APPENDIX H-1

Habitat Components of the Salton Sea Ecosystem Restoration

2006

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APPENDIX H-1
HABITAT COMPONENTS OF THE SALTON SEA ECOSYSTEM RESTORATION

The Salton Sea and adjacent areas supplied by Colorado River water provide vital habitat for fish and wildlife, particularly migratory and resident birds. However, the changing physical and biological characteristics of the Salton Sea are adversely affecting the value of the Salton Sea ecosystem for fish and wildlife, as well as other uses.

This appendix provides information on the historical context and need for restoration, and information on fish and wildlife species found at the Salton Sea. This appendix also identifies possible habitat components that could comprise a restored Salton Sea ecosystem, including the physical and biological requirements needed to support fish and wildlife dependent on the Salton Sea. These components were developed in consideration of the realities of water supply and feasibility of the infrastructure needed to maintain habitat values over the long term. Development of the habitat components represents collaboration between biology and engineering, in which multiple conceptual designs were reviewed, modified, and refined. Input also was provided by representatives of the Salton Sea Advisory Committee and scientists[1] with expertise related to the Salton Sea.

This appendix also provides the technical basis for the habitat creation and restoration components, and the configuration of the alternatives to be analyzed in the Draft Programmatic Environmental Impact Report (PEIR). The analysis of alternatives in the PEIR is conducted at a programmatic level, with the details of implementation deferred to project-level analyses. This appendix similarly addresses habitat restoration at a programmatic level and is not intended to serve as the detailed design of the habitat restoration components. Nonetheless, the analysis of elements described here is intended to provide sufficient detail to give reasonable assurance that the restoration components could be feasibly implemented and that they should perform as expected.

IMPORTANCE OF THE SALTON SEA ECOSYSTEM

The Salton Sea is adjacent to the lower Colorado River delta and the northern portion of the Gulf of California. Due to the significant loss of wetlands in California and other areas, the Salton Sea ecosystem has become one of the most important wetlands to birds in North America (CRBRWQCB, 2003) and supports some of the highest levels of avian biodiversity in the southwestern United States (Shuford et al., 2002). Recent studies have documented the great importance of the Salton Sea ecosystem in providing habitat for migrating and resident waterbirds, particularly Pacific Flyway waterbirds (Shuford et al., 2002). Over 400 resident, migratory, and special status bird species have been recorded in the Salton Sea area since its formation (Cooper, 2004), with about 270 of those species using the Salton Sea on a fairly regular basis.

In addition to the diversity of birds, studies have indicated that the large number of individual birds using the Salton Sea is even more ecologically relevant than the number of species. The Salton Sea for birds has become an "internationally-significant stopover site for hundreds of thousands of transients moving north and south along the 'Pacific Flyway,' and east into the Great Basin/Prairie Pothole region" as well as the

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[1] As part of the development of alternatives, DWR convened a group of scientists with expertise in technical issues at the Salton Sea for the purpose of obtaining informal consultation and technical advice on various aspects of the restoration components. This group, led by Doug Barnum (USGS Salton Sea Science Office), met on several occasions with representatives of DWR, DFG, and the consultant team over the course of the development of the alternatives. Experts participating in the meetings included Christopher Amrhein (U.C., Riverside), Jack Crayon (DFG), Richard Gersberg (San Diego State University), Kathy Molina (LA County Natural History Museum), Geoffrey Schladow (UC, Davis), Teresa Pressor (USGS), Pat Chavez (USGS), Harry Ohlendorf (CH2M HILL), and Nils Warnock (PRBO).

"winter home for hundreds of thousands of individuals of numerous species from around North America" (Cooper, 2004). For several species, the Salton Sea supports a significant portion of their regional or North American populations. For example, an estimated 75 percent of the New World population of eared grebes has been recorded at the Salton Sea (Patten et al., 2003). In addition, 23 to 30 percent of the North American breeding population of American white pelicans (Shuford et al., 2000), 50 percent of the winter population of ruddy ducks (Patten et al., 2003), and 40 percent of the California breeding population of black skimmers have been recorded at the Salton Sea (Collins and Garrett, 1996). The nesting colony of gull-billed terns is the largest in the western United States (Molina, 2000). In terms of overall shorebirds, the Salton Sea is the most important area in the Intermountain and Desert region of the West in the spring and the second most important, after Great Salt Lake, in the fall. The Salton Sea is one of only three sites, along with the Central Valley of California and the Willamette Valley of Oregon, where tens of thousands of shorebirds winter (Shuford et al., 2004), and qualifies for designation as a site of international importance to shorebirds under criteria of the Western Hemisphere Shorebird Reserve Network (Harrington and Perry, 1995, cited in Shuford et al., 2002). The Salton Sea supports the largest population of wintering snowy plovers in the interior of western North America (Shuford et al. 1995), and is one of a handful of key breeding areas in the interior of California (Page et al. 1991, cited in Shuford et al., 2002).

The Salton Sea is one of the most important sites in western North America for migrating black terns (Shuford et al., 2002), with "tens of thousands" reported during the period of peak occurrence in mid-summer (Small 1994, cited in Shuford et al., 2002), representing about 10 percent of the global population (Cooper, 2004). Surveys indicate that the Salton Sea ecosystem supports about 40 percent of the endangered Yuma clapper rail's entire U.S. population (Cooper, 2004).

The Imperial Valley is one of the most important areas for white-faced ibis in western North America, with at least 30 percent of the global population during the fall migration and 50 percent of the California wintering population (Cooper, 2004). It also supports an estimated 70 percent of the California population of burrowing owls (Shuford et al., 1999). Surveys in 1999 indicate that the Imperial Valley is even more important than previously recognized for the mountain plover, supporting up to 40 percent of the species' entire population (Shuford et al., 2002).

Since the Salton Sea's formation in 1907, a series of aquatic communities have thrived. A single native fish, the endangered desert pupfish, had inhabited two streams and several springs in the Salton Trough prior to formation of the Salton Sea, and it persists today in agricultural drains and shallow parts of the Salton Sea. The other original members of the Salton Sea fish community were fish from the Colorado River carried by the flow into the Salton Sea as it was filling, including carp, striped mullet, humpback sucker, rainbow trout, and bonytail chub (Walker, 1961; Evermann, 1916). By 1915, the striped mullet supported a commercial fishery, which persisted through the early 1950s (Hendricks, 1961).

In the late 1940s to the mid-1950s, the California Department of Fish and Game (DFG) stocked more than 30 species of marine fishes as the salinity of the Salton Sea approached ocean levels; populations of orangemouth corvina, sargo, and gulf croaker became established and thrived (Walker, 1961). A handful of introduced marine invertebrates, pileworms and barnacles in particular, came to dominate the lower end of the aquatic food chain, and provided the forage base that supported elevated levels of fish populations and bird use. During the 1960s and 1970s, tilapia unexpectedly invaded the Salton Sea from irrigation drains, and ultimately came to dominate the fish community. The tilapia population provided a new abundant forage base for the marine sport fish and fish-eating birds.

Supported by the inflows of nutrients from agricultural drain water, the Salton Sea fisheries from 1960 to 2000 were phenomenally productive, possibly among the most productive in the world (Costa-Pierce and Riedel, 2000a). These popular fisheries were a fundamental driver of the burgeoning recreational use of the Salton Sea during those decades. An economic study of the Salton Sea published in 1969 (Harris et al., cited in CIC Research, Inc., 1989) estimated the visitor use of the Salton Sea at 1,500,000 recreation days[2] annually. Two thirds of these recreation days were for sport fishing.

As salinity and nutrients increased in the Salton Sea over time, wildlife health was negatively affected, and chronic large scale die-offs of fish and birds fueled the public perception of a deteriorating ecosystem. Starting in 2000, all sport fish populations at the Salton Sea underwent a dramatic decline, as deteriorating water quality apparently reached a threshold for their survival. Sargo, gulf croaker, and orangemouth corvina have been undetectable in DFG gill net sampling since mid-May, 2003. Tilapia populations have rebounded since their lowest levels in 2003, but currently persist in the Salton Sea at levels that are only 10 percent of those recorded in the 1990s.

HABITAT RESTORATION CONSIDERATIONS

Goals and Objectives

The value of the Salton Sea area to fish and wildlife is dependent on the amount and quality of water flowing into the Sea. Future projections of inflows to the Salton Sea indicate that inflows would diminish considerably from current levels. This requires the alternatives to meet restoration objectives with less water than is currently available. The future inflow projections (Appendix H-2) also suggest that many of the areas that currently provide high value for birds (e.g., river deltas) would be altered and the future value of these important habitat areas could be compromised as a result of receding surface water elevations. Other areas, such as those that include important features such as snags and islands, would no longer function as habitat as the Salton Sea recedes because these features would not be in close proximity to the shoreline and open water. Changes in water quality would influence the quality of habitat in many areas. Because of these circumstances, the restoration goals place greater emphasis on retaining (to the extent possible) and replacing the habitat functions historically provided by the Salton Sea as a means to continue to support fish and wildlife. The restoration goals also focus on bird species associated with Salton Sea habitats (deep open saltwater, shoreline/shallow saltwater, and river mouths/deltas) (Attachment H1-1). The following describes various factors that were considered as part of the restoration and the extent to which they influenced the ultimate layout and configuration of the alternatives.

The following goals and objectives of restoration include those defined in Chapter 1 and those added based on input from members of the Salton Sea Advisory Committee and others. The primary habitat goal for restoration is:

- Restore Salton Sea ecosystem and the permanent protection of the wildlife dependent on that ecosystem.

Specific objectives include, to the maximum feasible extent, the following:

- Restore long term stable aquatic and shoreline habitat for the historic levels and diversity of fish and wildlife that depend on the Salton Sea;
- Promote habitat diversity by maintaining a mosaic of habitat types within and adjacent to the Salton Sea in an arrangement that enhances their value to fish and wildlife;
- Enhance the quality of habitat through improvements in water quality and water management;
- Promote the effective use of the available water resources to create habitats that provide for species diversity and abundance; and

[2] A “recreation day” represents one person engaged in a recreational activity during the day, regardless of the time spent in that activity.

- Incorporate flexibility in the facility and habitat designs to help accommodate adaptive management and the ability to respond to future changes in conditions and the status of individual fish and wildlife species (encourage solutions that rely on natural processes and minimize intensive, sustained interventions).

Historic Levels of Bird Use

One of the primary objectives is to "restore long term stable aquatic and shoreline habitat for the historic levels and diversity of fish and wildlife that depend on the Salton Sea." While diversity, which is defined as the number of species or species richness, has remained relatively stable over the recent past (e.g., comparing Shuford et al., [2000] vs. Los Angeles Natural History Museum, [unpubl. data from 2005]), the levels of use by species and species groups (e.g., pelicans, grebes, gulls) have not. Defining the term "historic levels" is complicated by the dynamic history of the Salton Sea in terms of area, depth, and salinity, among other characteristics, and the changes in the levels of bird use over time. For example, American white pelican numbers appear to have fluctuated in response to changes in fish populations (DFG and Service, unpubl. data), which have changed in response to water quality changes and other factors in the Salton Sea. This complicates interpretation of at-Sea changes because bird use, particularly for migrants, also fluctuates in response to biotic and abiotic factors outside the Salton Sea area. For instance, the numbers of birds that visit the Salton Sea during migration could be influenced more by conditions on breeding grounds elsewhere than at the Salton Sea. Understanding changes in bird numbers at the Salton Sea is further complicated by the relative scarcity of long term comprehensive surveys. Many bird surveys have been conducted at the Salton Sea, but most are of short duration and limited to few species. Also, these surveys frequently apply different survey techniques or protocols, which complicate the ability to compare results. The survey conducted in 1999 represents the most comprehensive bird survey at the Salton Sea (in which the majority of the avifauna was seasonally surveyed over the course of the year [Shuford et al., 2000]).

For the purpose of developing alternatives intended to achieve the objective of restoring long term, stable aquatic and shoreline habitat for historic levels and diversity of fish and wildlife that depend on the Salton Sea, historic levels were identified for selected bird species based on available survey results (Tables H1-1 and H1-2). These included surveys conducted since 1978 by the Point Reyes Bird Observatory, Los Angeles Natural History Museum (Kathy Molina), San Bernardino County Museum (Robert McKernan), and a few other sources, which were selected because they were comprehensive and generally spanned multiple years. Identified historic levels also serve as the basis for evaluating the relative performance of the action alternatives.

The bird species selected to represent historic levels were those that have a special status designation or use the Salton Sea in numbers that represent significant segments of their regional or North American populations. Specifically, species were included if they were listed as State Threatened, State Endangered, Federally Endangered, Federally Threatened, on the DFG Bird Species of Special Concern list, species considered Highly Imperiled or of High Concern under the National Waterbird Conservation Plan, species or subspecies with a 4-5 priority score under the U.S. Shorebird Conservation Plan, on the U.S. Department of the Interior, Fish and Wildlife Service's (Service) Birds of Conservation Concern - BCR 33 list, or a species where more than 10,000 birds were counted on single survey at the Salton Sea. In all, 28 species that met these criteria were identified.

The range in numbers of birds using the Salton Sea was identified for each of the 28 species and measures of central tendency calculated (mean and median) for each season. The abundance data reflect survey results from areas at or immediately adjacent to the Salton Sea where restoration activities would be concentrated. For the purpose of identifying numbers that most likely represent the historic level of use of the Salton Sea by these species, median values were used when survey data were available for five or more years; otherwise, the mean value was used. The values used to represent historic levels in each season are presented in Table H1-2.

Table H1-1
Number of Surveys Conducted for Each Species by Year (1978–2005)

Species	List	Year																		
		78	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	99	05
Aechmophorus spp.[a]	A		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	
American Avocet	A									2	2	2	2	1	1				4	2
American White Pelican	BSSC, A		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	2
Black Skimmer	BSSC, BCC, WP																		4	2
Black Tern	BSSC																		4	2
Black-necked Stilt	A									2	2	2	2	1	1				4	2
Brown Pelican	FE, SE																		4	2
California Gull	A																		4	2
Cattle Egret	A																		4	2
Double-crested Cormorant	BSSC, A																		4	2
Dunlin	SP									2	2	2	2	1	1				4	2
Eared Grebe	A						5	5	5	5	5	5							4	2
Gull-billed Tern	BSSC, BCC, WP																		4	2
Least Bittern	BSSC																			2
Long-billed Curlew	BSSC, SP									2	2	2	2	1	1				4	2
Marbled Godwit	SP, BCC									2	2	2	2	1	1				4	2
Red-necked Phalarope	SP, A									2	2	2	2	1	1				4	2
Redhead	BSSC																			2
Ring-billed Gull	A																		4	2
Ruddy Duck	A		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	2
Snowy Egret	WP																		4	2
Snowy Plover	BSSC, SP, BCC	1							1	2	2	2	2	1	1				5	3
Western Sandpiper	SP, A									2	2	2	2	1	1				4	2
Whimbrel	SP, BCC									2	2	2	2						4	2
White-faced Ibis	BSSC, A																		4	2
Wood Stork	BSSC, WP																		4	2

Table H1-1
Number of Surveys Conducted for Each Species by Year (1978–2005)

Species	List	Year																		
		78	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	99	05
Yuma Clapper Rail	FE																		1	
Dowitcher spp.[b]	SP, A									2	2	2	2	1	1				4	2

List = reason for inclusion: BSSC = DFG's Species of Special Concern; SE = State Endangered; ST = State Threatened; FE = Federally Endangered; WP = National Waterbird Conservation Plan; species considered Highly Imperiled or of High Concern; SP = US Shorebird Conservation Plan species or subspecies getting a 4-5 priority score; BCC = Service's Birds of Conservation Concern - BCR 33; A = >10,000 birds counted on single survey

[a] Includes Clark's and western grebes.
[b] Includes long-billed and short-billed dowitchers.

Table H1-2
Historical Abundance of Selected Bird Species by Season at the Salton Sea

Species	Fall	Winter	Spring	Maximum
Aechmophorus spp.[a]	n/a	11,213	7,872	31,244
American Avocet	13,419	5,836	7,001	19,382
American White Pelican	788	21,500	8,625	46,500
Black Skimmer	637	15	6	777
Black Tern	3,703	1	2	4,011
Black-necked Stilt	12,059	3,941	3,184	19,255
Brown Pelican	2,671	97	0	3,346
California Gull	7,410	8,146	3,293	11,313
Cattle Egret	608	32	238	1,213
Double-crested Cormorant	1,695	13,010	11,160	18,504
Dunlin	1	609	542	2,258
Eared Grebe	46	1,723,458	1,653,130	2,227,243
Gull-billed Tern	34	0	69	69
Least Bittern	0	0	n/a	0
Long-billed Curlew	1,022	658	34	3,761
Marbled Godwit	880	1,283	877	3,190
Red-necked Phalarope	1,116	5	101	12,265
Redhead	182	0	n/a	182
Ring-billed Gull	8,308	24,129	5,049	28,523
Ruddy Duck	73	21,792	4,522	32,680
Snowy Egret	979	335	350	1,103
Snowy Plover	129	214	226	462
Western Sandpiper	34,678	4,714	38,225	67,343
Whimbrel	17	0	3,243	9,837
White-faced Ibis	169	397	434	826
Wood Stork	7	0	0	8

Table H1-2
Historical Abundance of Selected Bird Species by Season at the Salton Sea

Species	Fall	Winter	Spring	Maximum
Yuma Clapper Rail	n/a	n/a	279	279
Dowitcher spp.[b]	8,237	6,356	12,109	26,443

Table values represent medians when 5 or more surveys were available, otherwise seasonal values are the averages of fewer than 5 survey values. Total number of surveys (all seasons) is identified in Table H1-1.

Fall = August and September
Winter = November to February
Spring = March to May

[a] Includes Clark's and western grebes.
[b] Includes long-billed and short-billed dowitchers.

Area Needed to Support Historic Levels of Bird Use

As previously described, one of the objectives is to maintain the historic diversity and levels of use at the Salton Sea, with an emphasis on the avian community. To maintain bird species richness, habitat at the Salton Sea following restoration must support the same functions that were supported at the Salton Sea in the recent past, such as invertebrate and fish production, nesting and roosting structures, undisturbed loafing areas, and shallow and open water foraging areas. Assuming the habitat components (e.g., Marine Sea and Saline Habitat Complex) are successful in performing as expected, the restored Salton Sea area should continue to support the same bird species. The level of use, however, would be influenced in large part by the quality, type, and amount of habitat available for use by the avian community.

The amount of area needed to achieve the restoration objectives was initially approached by determining the physical area of habitat at the Salton Sea that was available for use by birds in recent years. The shallow shoreline of the Salton Sea, which provides habitat for shorebirds, wading birds, and other species, was defined as the margin of the Salton Sea to a depth of 3 feet. Most shorebirds forage at depths less than about 6 inches, but because of changes in water surface elevation caused by wind action and seasonal changes in inflow, the effective foraging area available to shorebirds is likely much larger than the area defined by a depth of less than 6 inches. A depth of 3 feet was used to account for this additional foraging area. This total area along the margin of the Salton Sea (0 to 3 feet deep) thus represents the physical area that was available for use by the shorebirds and other species that use shoreline habitat in recent years. The aerial extent of this habitat area can be defined at any given surface elevation. At the current surface elevation of about -228 feet mean sea level (msl), the area from 0 to 3 feet deep and available for bird use (primarily shorebirds) is about 6,000 acres.

The open water area of the Salton Sea extending beyond the 3-foot depth contour covers significantly more area than shoreline from 0 to 3 feet in depth. At the current surface elevation of about -228 feet msl, the open water portion of the Salton Sea available for use by birds is in excess of 200,000 acres, which is an area over five times the size of Mono Lake. Therefore, it is unlikely that bird use of the open water areas of the Salton Sea is limited by physical space. The fish and invertebrate productivity of the open water areas of the Salton Sea is not uniformly distributed. The Salton Sea becomes stratified over several months of the year (Appendix D), which can result in anoxic conditions over large expanses of the Sea Bed due to decomposition of organic matter and a lack of mixing. During these periods, the areas in the anoxic layer do not support invertebrate or fish communities though the overlying water that remains oxygenated could continue to support these species. However, studies have found that fish concentrate around the perimeter of the Salton Sea and in estuarine areas in the summer due to poor oxygen conditions in the more open waters (Riedel et al., 2002). In addition, anaerobic decomposition in the hypolimnion produces hydrogen sulfide (a compound toxic to aquatic life) that is mixed into the water column when the stratification breaks down as a result of wind action or seasonal changes in temperature. These events frequently result in substantial fish kills.

As a result of these conditions and events, most of the invertebrate and fish production and bird activity (including shorebirds) occurs in the near shore areas. Bird use in the near shore areas also is influenced by proximity to fresher water. The disproportional use of the near shore areas relative to the central portion of the Salton Sea is supported by observations of both the fish and bird communities. Costa-Pierce and Riedel (2000) indicated that tilapia density was greatest and catch rates were highest in estuarine areas off the mouth of the New and Alamo rivers and in nearshore areas along the margin of the Salton Sea out to about 6 feet in depth. Jehl and MeKernan (2002) indicated that eared grebes were observed in highest densities in the nearshore areas. Based on the inconsistent water quality characteristics of the central portion of the Salton Sea and observations of fish densities and bird use, the surface area of open water that represents nearly the entire habitat for waterbirds likely is represented by the area extending from the shoreline out to a distance of 0.6 miles. At a surface elevation of -228 feet msl, the area within 0.6 mile of the shoreline is 37,823 acres, which includes the shoreline area described above. Therefore, the physical area that supported the majority of the recent level of bird use is roughly 38,000 acres.

This estimate of the physical area historically used by birds provides guidance regarding the amount of habitat needed to maintain historic numbers if the quality of habitat created through restoration is similar to or better than historic conditions in the areas supporting the highest bird use. Water quality would be an important aspect of the habitats created through restoration and would influence the value of these areas to birds. Based on the evaluation of water quality in each of the habitats that would contribute to restoration (e.g., Saline Habitat Complex and Marine Sea), these habitats are expected to support the conditions necessary to produce the habitat characteristics required by birds (Appendix D). Additional considerations include the unique characteristics of the current habitat, such as islands, snags, brackish water inflow, and proximity to freshwater marsh and agricultural lands.

Given the uncertainty regarding the ability of restored habitats to support historic levels of bird use, greater than 38,000 acres of restored habitat likely would be needed to meet the restoration objectives. Rather than attempt to define a target number of acres needed to retain historic levels of bird use, most of the alternatives maximize the use of available water for the creation and maintenance of habitat. All of the water bodies associated with the alternatives would support some level of bird use, except for a future Brine Sink when salinities exceed its ability to support a forage base. The various habitat combinations and amounts unique to each alternative would support different levels of bird use and would be expected to perform differently relative to meeting historic levels of bird use.

To assess the relative performance of each alternative relative to historic conditions, a model developed to evaluate the effects of habitat conversion of the San Francisco Salt Ponds on bird use was adapted for use at the Salton Sea (Appendix C). In the model, habitat-specific bird densities for selected bird species were multiplied by the area of the corresponding habitat type, and overall bird numbers were estimated by summing across habitat types in each alternative. For habitat components that would be expected to retain the habitat values of the current Salton Sea, such as the shoreline and Marine Sea, bird densities based on previous studies at the Salton Sea were used. The surveys conducted in 1999 (Shuford et al., 2000) generated sufficient information to determine the densities by habitat for a suite of representative bird species at the Salton Sea. Because shoreline bird densities vary considerably according to landscape context (e.g., surrounding managed wetlands and cropland) and water depth, these densities were estimated for shoreline segments within 500 meters (m) (1,640 feet) of the shoreline using statistical models, while densities beyond 500 meters (1,640 feet) from the shoreline were considered constant over the entire open water surface.

However, various alternatives include habitat components that currently are not part of the Salton Sea ecosystem and for which no site-specific density information is available, such as the Saline Habitat Complex and those areas that are expected to be managed at salinities considerably outside the range of the conditions currently present at the Salton Sea. For habitats not currently found at the Sea (Saline Habitat Complex) and existing areas that would have higher salinities in the future, data from salt ponds adjacent to San Francisco Bay with higher salinities were used to adjust the observed Salton Sea densities for increased salinities. The salt ponds possess similar characteristics to those anticipated in the Saline Habitat Complex for factors including depth, salinity, and forage base. Bird densities in the Saline Habitat Complex and other higher salinity habitats were estimated by calculating mean densities by depth category from the San Francisco Bay salt ponds, and multiplying those densities by an adjustment factor based on densities observed in existing Salton Sea shoreline habitats.

These densities, in consideration of the number of acres of each of the habitats that would be available under a given alternative, were used in the PEIR (Chapter 8) as the basis for evaluating relative performance of each of the alternatives in meeting historic bird levels for each of the selected bird species and achieving objectives described in Chapter 1. This analysis was intended to provide an assessment of potential bird use at the Salton Sea following restoration and the relative differences among alternatives as an indicator of performance.

Non-avian Terrestrial Wildlife

One of the objectives includes the restoration of the Salton Sea ecosystem and the permanent protection of the wildlife dependent on that ecosystem. Another objective provides for the maximum feasible attainment of restoration for the historic levels and diversity of fish and wildlife that depend on the Salton Sea. Birds comprise the most visible and one of the most important wildlife groups at the Salton Sea. However, other wildlife groups, including mammals, reptiles, and amphibians also are supported in the Salton Sea area. These wildlife groups are associated principally with the upland portions of the area, particularly the refuges, agricultural areas, and desert scrub and non-native vegetation that borders the Salton Sea.

For completeness, it is necessary to recognize the importance of freshwater marsh habitat and agricultural lands to many birds that use Salton Sea habitats. Likewise, the importance of non-avian wildlife in these areas must be acknowledged. With few exceptions, most birds and other wildlife that use the freshwater marsh and agricultural lands are not influenced by the Salton Sea or the changes that would occur through implementation of the alternatives. During project-level analyses, more detailed evaluations would be conducted of specific areas and associated habitats that could be affected by construction and operations and maintenance activities.

Fish

Achieving the restoration of historic levels and diversity of fish requires the recognition of three functional groups of fishes in the Salton Sea ecosystem: sport fishes, forage fishes, and protected species (desert pupfish). There are group-specific considerations raised by the different habitat components proposed in the alternatives. The three marine fish species (gulf croaker[3], orangemouth corvina, and sargo) and tilapia[4] (primarily Mozambique hybrid tilapia) have historically functioned as both sport fish and forage fish to varying degrees, depending upon the size of individual fish. Orangemouth corvina have been the most sought after sport fish, while tilapia have turned out to be a main driver of enhanced bird foraging opportunities at the Salton Sea because of its more recent introduction and population expansion. Longjaw mudsucker and sailfin molly also are important forage fish when they are present in large numbers.

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[3] The official common name for this species is Bairdiella (American Fisheries Society Special Publication 29); however, the name "gulf croaker," which is the local common name, is used throughout this document.

[4] The term "tilapia" is used here to refer to two cichlid species found at the Salton Sea. The dominant species in the open waters of the Salton Sea is a hybrid of the Mozambique tilapia (*Oreochromis mossambicus*) and the Wami tilapia (*O. urolepis*) referred to throughout the document as "Mozambique hybrid tilapia." The species inhabiting the drains around the Salton Sea is the "redbelly tilapia" (*Tilapia zillii*).

The desert pupfish is an example of a Salton Sea resource with no replacement options. This species has demonstrated a surprising adaptability to changes over time in water quality, aquatic community structure, and habitat structure. Still, care must be taken to ensure that restoration efforts incorporate design elements that facilitate gene flow among and within the three natural populations that are recognized as Tier I populations in the species' Recovery Plan. These three populations are currently spatially segregated in the wild in Salt Creek, San Felipe Creek/San Sebastian Marsh, and the agricultural drains and shoreline pools of the Salton Sea proper.

Unlike the bird community, the fish community of the Salton Sea has changed dramatically from recent conditions, both in species composition and levels (see discussion above on the importance of the Salton Sea Ecosystem). Since the initiation of quarterly fish monitoring efforts by DFG in 2003, the marine sport fish have disappeared from the fish samples at the Salton Sea and the once extremely abundant tilapia has diminished substantially in number. Improvement of aquatic habitat conditions in the Salton Sea through restoration would retain fish as an important component of the ecosystem and serve to support fish-eating birds. Therefore, the conditions necessary to support the fish species recently occupying the Salton Sea, particularly tilapia, were considered in the development of restoration components.

Because of recent changes in the fish community, achieving historic fish diversity and abundance would require introductions or reintroductions of fish species to the ecosystem. Decisions regarding whether to introduce additional fish species and which species would be appropriate for introduction would be made in project-level analyses. It is possible that other species of fish could provide the same function as the fish recently in the Salton Sea. The most prudent approach would be to re-create the species composition of the fish community that persisted and provided excellent sport and forage fisheries during the last several decades. The specific conditions within restored water bodies at the Salton Sea would dictate which species could be successfully introduced. In addition, the specific objectives of any future introduction would drive species selection. Factors that would serve in selecting species for introduction include the ecological role that species would fill, its contribution to a more stable ecosystem, its potential threat to desert pupfish populations, and its ability to provide opportunities for a sport fishery.

Desert Pupfish Connectivity

The only fish native to the Salton Sink is the desert pupfish, which existed in Salt Creek, San Felipe Creek, and several springs that were inundated by the flooding of the Salton Trough. Desert pupfish persist today in both creeks, and have become established in the terminal sections of agricultural drains that flow directly to the Salton Sea on the south and north shores, as well as in the shallow water margins of the Salton Sea itself. These fish are presumed connected because they are present in the Salton Sea and in pools created along its margin. While use of the Salton Sea for movement among sites has not been documented, this premise is supported by documented movement between San Felipe Creek and shoreline pools, and similar movement between agricultural drains and shoreline pools (Sutton, 2000). Also, DFG has observed dramatic short term fluctuations in the number of adult desert pupfish in individual drains, suggesting an influx of individuals from the Salton Sea (J. Crayon, 2006). Desert pupfish apparently are capable of moving freely between the relatively fresh water in the agricultural drains and the highly saline environment in the Salton Sea.

Desert pupfish are State and federally listed as endangered, primarily as a result of habitat loss (e.g., dewatering of springs), pollution, and introduction of exotic species that either prey upon desert pupfish or compete for available resources (Marsh and Sada, 1993). They are very tolerant of extreme water quality conditions, and have been held in the laboratory in water with salinity greater than 98,000 mg/L (Barlow, 1958). The ability of desert pupfish to tolerate high salinity, high pH, and low dissolved oxygen apparently contributes to their ability to persist at the Salton Sea. Martin and Saiki (2005) suggested that desert pupfish abundance in Salt Creek and several agricultural drains is generally highest in areas where water quality extremes seemingly limit the occurrence of other fish. Currently, the relatively high salinity and water quality dynamics of the Salton Sea limit some of the fish that prey upon desert pupfish, especially now that the marine sport fish are apparently absent.

Under current conditions at the Salton Sea, individual desert pupfish inhabiting creeks and drains that flow into the Salton Sea are presumed to move along the margins of the Salton Sea and among drains. This movement, which provides the opportunity for genetic exchange among desert pupfish, reduces the potential deleterious effects of isolation of individual populations. It also provides the opportunity to recolonize these same areas in the event a local population is extirpated. In the future without restoration, salinity in the Salton Sea would continue to increase, ultimately to a point that would exceed the salinity tolerance of desert pupfish. Under that scenario, movement of individual desert pupfish among the creeks and drains would be eliminated and the risk of extirpation of local populations increased.

Restoration can reduce or avoid the potential impacts to desert pupfish associated with restricted movement by incorporating features or facilities that would retain connectivity among the areas that currently support desert pupfish. Providing connectivity that allows movement of desert pupfish among habitats around the Salton Sea could be achieved by mimicking the function currently provided by the Salton Sea through development of a continuous water body that links the desert pupfish that use the drains and creeks. Actively transporting desert pupfish to ensure genetic exchange among isolated populations or to reintroduce desert pupfish to previously occupied areas was not a consideration in the development of alternatives. For the purpose of guiding programmatic design of constructed water bodies that would facilitate desert pupfish movement, several factors were considered, including extent of the connection, water quality, potential predators, and long term operations and maintenance.

Maintaining some level of connectivity of desert pupfish at the Salton Sea is an objective of all alternatives. Although maintaining connectivity among all geographic areas is desired, the connection of free-flowing creeks and drains to the Salton Sea would be altered under several of the alternatives in order to accommodate the infrastructure needed to create habitat and provide for air quality management. Complete connectivity among all areas was not considered an absolute requirement of the alternatives. However, those alternatives that retain the greatest level of connectivity would provide greater benefit to desert pupfish than those that isolate areas and would perform better in achieving the overall objectives of restoration.

Desert pupfish are observed most frequently in shallow water less than 30 centimeters (about 1 foot) deep with velocities less than about one foot/second (Black, 1980). For the purpose of providing guidance on the programmatic-level design of Pupfish Channels used to achieve connectivity, it was assumed that the water bodies used to connect desert pupfish habitat likely would have sufficient shallow water and diversity of depth to allow desert pupfish to find suitable conditions. Thus, no specific criterion was applied. For water velocity, however, these water bodies were designed to ensure the availability of areas with velocities of less than one foot/second.

Avian Disease

Several avian diseases have been identified at the Salton Sea that occasionally result in substantial bird losses. While these diseases would persist at the Salton Sea in the future, the occurrence, scale, and magnitude of these diseases might be influenced by the restoration. The primary diseases are summarized below.

Avian botulism results from ingestion of toxins produced by the bacterium *Clostridium botulinum*, and is considered the primary cause of bird die-offs at the Salton Sea (Service, 2006). This bacterium requires anoxic conditions, warm temperatures, and a protein source to produce the toxin. The bacterium generally exists as an encapsulated spore with little environmental effect. Little is known about the natural factors that cause the bacteria to leave the spore state and begin producing toxin. Several factors may play a role, including the bacterial host and environmental characteristics such as temperature and salinity. Decomposing plant and/or animal material can provide appropriate conditions for the bacteria to produce the toxin. Birds can then ingest the toxin directly or via invertebrates containing the toxin. Invertebrates are not affected by the botulism toxin that they ingest while feeding. Once birds are infected, a maggot cycle can begin and spread the bacteria to large numbers and species of birds that ingest the maggots.

Two types of botulism have been found at the Salton Sea. Type C botulism is typical for waterfowl and the most common botulism strain found in wildlife. The second type of botulism is Type E, which has been found largely in fish-eating birds. For the latter, fish die-offs from various causes result in conditions within the intestines of dying fish that allow botulism spores to germinate and produce the toxin. The birds that feed on the dying or dead fish then ingest the botulism toxin in the fish.

During a 4-month period in 1996, nearly 14,000 birds succumbed to botulism, including most waterfowl and fish-eating bird species found at the Sea. The number of deaths attributed to botulism in 1997 and 1998 decreased to an estimated 8,000 individuals in 1997 and fewer in 1998 (PRBO, 1998). Specific to the 1996 large-scale bird die-off at the Salton Sea, it is suspected that the large number of pelicans affected were associated with a die-off of tilapia. With the die-off of tilapia, large numbers of infected fish became available to fish-eating birds (PRBO, 1998). Over 10,000 pelicans were lost during the 1996 event.

Avian cholera is a contagious bacterial infection that spreads rapidly where waterfowl concentrate in large numbers. Avian cholera is caused by the bacterium *Pasteurella multocida*. The cholera bacteria can be transmitted by bird to bird contact, contact with secretions or feces of infected birds, or ingestion of food or water containing the bacteria. According to Sonny Bono Salton Sea National Wildlife Refuge (NWR) records, avian cholera was not suspected at the Salton Sea until 1979, when a large scale die-off of waterfowl was attributed to the disease (Friend, 2002). Large-scale die-offs occurred again in 1991-1992, 1996, and 1998, when over 11,000 waterfowl, shorebirds, and waders are suspected of dying from the disease (PRBO, 1998).

Newcastle disease is a highly contagious viral disease caused by infection with an RNA virus. Most information on the disease comes from agricultural resources because this disease has historically affected chickens. Similar to salmonellosis and avian cholera, Newcastle disease can be transmitted through feces, excretions, or affected corpses, and through ingestion of food or water containing the virus. Very little is known about this disease in the context of wild birds. All of the North American cormorant die-offs from Newcastle disease have occurred in breeding colonies. Mortality has occurred during the months of March through September. Newcastle disease has been confirmed as the cause of two separate die-offs in 1997 and 1998 (resulting in the deaths of 1,600 individuals and 3,000 pairs of double-crested cormorants, respectively). Prior to these events, the disease was not known to occur in double-crested cormorants west of the Rockies.

In addition to known diseases, significant bird die-offs resulting from unknown causes occur at the Salton Sea. In 1992, an estimated 150,000 eared grebes died at the Salton Sea, which represented about 6 percent of the North American population. Dead grebes collected at the time were analyzed for multiple factors to determine the cause of death, but no clear cause could be identified (Meteyer et al., 2004). Hypotheses for the unexplained die-off include the interactive effects of contaminants, immunosuppression, unidentified biotoxins or pathogens, impairment of feather waterproofing leading to hypothermia, or a unique manifestation of avian cholera.

All of these diseases likely will persist at the Salton Sea, even under restored conditions. Most of the disease control would continue to be undertaken as management measures that respond to specific conditions or disease events. The specific project-level design of facilities and features could be developed to contribute to reduced incidence of disease. At the current programmatic-level planning scale, disease reduction was addressed through identification of salinity ranges that could reduce diseases (e.g., Type C avian botulism) and creation of conditions, particularly water quality that would improve the overall health of the ecosystem.

Uncertainty and Adaptive Management

Future changes in Salton Sea inflow, water quality, and location and extent of available habitat will significantly alter the character of the Salton Sea relative to current and recent conditions. The restoration objectives attempt to retain the habitat function and value of the Salton Sea through retention or creation of water bodies and features to support habitat for fish and wildlife. Expectations regarding the performance of these restoration components are based on the current understanding of recent habitat function at the Salton Sea, modeled or deduced predictions of water quality, food web interactions, and species requirements/use. While uncertainty regarding the level of use by birds using the Salton Sea area in the future exists, the basic assumption that the area would continue to attract and support birds is reasonable for the following reasons:

- The water source for future habitats would remain similar;
- The water bodies created through restoration likely would be managed to maintain conditions supporting invertebrates and fish that are tolerant of the conditions at the Salton Sea; and
- The increased opportunity for habitat management would allow adjustment to change and the ability to better respond to stressors such as disease.

Similarly, there would be uncertainty regarding invertebrate and fish production. This uncertainty has more to do with which species ultimately would comprise the community than whether invertebrate and fish production would occur. Several invertebrate species (e.g., pileworm) have recently played a significant role in supporting birds at the Salton Sea. Therefore, creating conditions that continue to support these species or alternative species that provide a comparable food resource would be important. However, most of the invertebrate species that use the Salton Sea belong to families composed of multiple species that are adapted to a wide range of aquatic conditions (e.g., Chironomidae). Changed conditions resulting from restoration, such as changes in salinity, might not support the same species of the invertebrate community that currently occur at the Salton Sea, but it is likely that conditions would remain within a range that would support various representatives of those same taxa and a productive invertebrate community.

The ultimate composition of the fish community also is uncertain, but, unlike the invertebrates, natural colonization by fish species tolerant of those conditions may not occur. As described above, the intentional introduction of fish species might be necessary to meet the objective of maintaining diversity.

The level of uncertainty would be reduced considerably in the project-level analyses. Additional focused analyses and studies likely would be conducted to clarify the details of the restoration design and to refine assumptions and predictions about future performance. Pilot projects currently underway to examine the efficacy and feasibility of constructed saline, shallow water ponds in providing habitat for birds and other wildlife also would contribute to reducing the level of uncertainty. Even with clearer focus on the direction of the program, however, ecosystem restoration at the Salton Sea would require a significant monitoring and adaptive management component. Despite the large number of studies that have been performed at the Salton Sea, many aspects of how the system functions are not well understood. Studies conducted to date generally focus on specific aspects of the system without the overall integration needed to gain an in-depth understanding of the relation among the various components of the system and the cause of observed change. Most of the resource monitoring efforts likewise lack a comprehensive and long term approach needed to evaluate species trends and inform future management.

Because of the uncertainty, an integrated, comprehensive monitoring and adaptive management program would be vital to the future success of ecosystem restoration. An integrated monitoring program for the Salton Sea ecosystem restoration likely would include elements such as the following:

- A comprehensive monitoring strategy that defines uncertainty and the questions requiring resolution;
- A clear linkage between data collected and actions within management control;
- Commonly agreed-upon sampling locations and protocols;
- A time period of sufficient duration to identify population trends and causal relationships; and
- A single entity with dedicated funding to oversee monitoring activities and house a common database.

Ultimately, an integrated and comprehensive monitoring program and sound adaptive management would protect the substantial investment in restoration and help meet goals and expectations. Within this context, adaptive management implies a directed approach designed and monitored in a way that evaluates performance and generates information that would be useful to adjusting future management to meet goals.

Adaptive management and possibly the ultimate success of a restoration program also would be influenced by the flexibility of the restoration design and ability to easily alter future management. Habitat components that have the flexibility to be changed easily (e.g., Saline Habitat Complex) would be better suited to adaptive management than components that allow less future manipulation because they are dependent on massive infrastructure (e.g., Marine Sea).

Geothermal Energy

The Salton Sea, particularly the southwestern portion, is situated over one of the most productive geothermal resources in the State. Coincidentally, a substantial portion of this geothermal resource is located in an area characterized by high levels of bird use. It is reasonable to assume that expansion of geothermal energy development in this area, including construction of facilities, would be considered in the future and that those facilities might conflict with meeting the habitat goals and objectives. The extent and placement of future facility construction, however, is currently unknown, as is the degree to which they might impact biological resources. Given the uncertainty about future expansion plans and the direction of restoration, specific accommodation of geothermal expansion was not included in the design and layout of alternatives. Further analysis to improve the compatibility of these uses and decisions regarding the priority of uses would be made in the future in the project-level analyses.

CURRENT SALTON SEA HABITATS

The Salton Sea supports habitats that function at multiple scales to contribute to the overall biological diversity and use of the area by fish and wildlife. For the purpose of defining the habitat elements, habitat was viewed at a coarse scale because of the programmatic-level nature of the analysis. The important habitats of the Salton Sea that were addressed include the shoreline of the Salton Sea and associated shallow water areas, open water, and areas where the New, Alamo, and Whitewater rivers enter the Salton Sea. Components of the shoreline and shallow water habitat addressed in the alternatives include islands and snags.

While the alternatives focus on habitats supported by the Salton Sea, other adjacent habitats contribute to the overall value of the area to wildlife, especially birds. Managed freshwater marsh and agriculture are two habitats that not only support species that rely exclusively on those habitats, but also provide birds with important foraging opportunities and freshwater for bathing and drinking. Collectively, these areas contribute to the value of the Salton Sea to birds. These habitats are not dependent on drainage inflows to the Salton Sea and they are not expected to change substantially in the future. Although these habitats were not the focus of restoration activities, they are described below to provide a broader context of the Salton Sea ecosystem.

In addition to the habitat value provided by managed freshwater marsh and agricultural fields, various other cover types not affected by the ecosystem restoration provide habitat and contribute to the diversity of birds in the Salton Sea ecosystem. The areas along the New, Alamo, and Whitewater rivers that support riparian trees and shrubs (primarily non-native plant species such as tamarisk) provide habitat for birds associated with tree/shrub habitats, including those that use these areas as a stopover during migration (Attachment H1-1). The desert (xeric) areas along the margins of the agricultural areas and the Salton Sea support birds associated with those habitats and several bird species common in the Salton Sea area are associated with developed areas and the trees and other landscape vegetation found in urban areas.

Shoreline/Shallow Water

The shallow shoreline areas that extend around the perimeter of the Salton Sea support an invertebrate community that serves as the forage base for numerous migratory and resident shorebirds. Shorebird use of these areas is generally concentrated in depths of 6 inches or less where invertebrate prey can be captured by wading and probing. The area occupied by this shallow water habitat is influenced by topography, with a relatively narrow band of habitat occurring on the steeper slopes (e.g., eastern and western shores) and considerably greater amounts of shallow habitat along the more gently sloping north and south shores. Along the southeastern edge of the Salton Sea, relatively flat areas periodically form large mudflats that substantially increase the availability of forage resources accessible to shorebirds. Wind action at the Salton Sea that routinely produces minor changes in water surface elevation along the shoreline also increases the amount of shallow water habitat at the Salton Sea by exposing areas that would be otherwise inaccessible to shorebirds. The perimeter of the Salton Sea (wetted edge) to a depth of 3 feet effectively represents the area where forage resources can be captured by shorebirds. The area comprising habitat along the shoreline (0 to 3 feet in depth) is about 6,000 acres. This area contains unvegetated mud flats and shoreline as well as a limited shoreline vegetation community dominated by tamarisk, with some iodine bush. About 293 acres of shoreline vegetation community dominated by tamarisk are identified in the University of Redlands (1999) database. The shore itself also functions as a resting area for many birds and as nesting for some (e.g., snowy plover and black-necked stilt).

The substrate along the Salton Sea shoreline, especially at depths of less than one foot, is composed of intact and broken barnacle shells and unconsolidated sediments ranging from coarse sand to gravel (Detwiler et al., 2002). Pools along the shoreline formed by sand or barnacle shell bars parallel to shore and connected to the Salton Sea and/or drains vary in size over time due to fluctuating Salton Sea elevations. Size of pools sampled for desert pupfish movement (Sutton, 2000) ranged from about 100 acres to less than one acre.

A variety of shorebirds and other bird species forage along the shallow water/shoreline of the Salton Sea. Invertebrates are the primary attraction for birds in these areas, but fish also contribute to the forage base. Representative species that forage primarily on fish include black skimmer, Caspian tern, Forster's tern, and great blue heron. Bird species that feed on invertebrates include black-necked stilt, American avocet, black-bellied plover, ruddy turnstone, and western sandpiper. Nesting/roosting colonies of gulls, terns, pelicans, and skimmers occur along or near the shoreline on remnant levee sections and shallow boulder and barnacle bars. Snowy plovers nest on the shore between Desert Shores and San Felipe Creek and between Bombay Beach and Wister (Patten et al., 2003).

At a water surface elevation of -228 feet msl, the Salton Sea has about 120 miles of shoreline. While the entire shoreline is generally available to birds, the pattern of use is not uniform. Of the 19 shoreline areas evaluated by Shuford et al. (2000), eight were identified as areas of particular importance to birds, most of which were located on the northern and southern portions (including southwest and southeast) of the Salton Sea. The Wister shoreline consistently exhibited the highest waterbird densities in each season. Shorebird abundances increased from lows in late May and early June to peak abundances from August to November.

Shoreline pools and shallow waters provide habitat for desert pupfish as well as other fish and invertebrates. In particular, shallow water provides important spawning and nursery areas for tilapia. The smaller fish in shallow waters feed on invertebrates as well as algal material. Rocky shoreline habitats also provide valuable refugia for invertebrates during periods when hypoxic or anoxic conditions persist in the Salton Sea (Detwiler et al., 2002). The rocky substrates have a high invertebrate (pileworm and amphipod) production rate through summer (Detwiler et al., 2002).

Open Water

Extending from the shallow shoreline, the vast majority of the area of the Salton Sea is occupied by open water that provides habitat for a variety of fish and wildlife. The distribution of fish and wildlife in the open water is concentrated along the near shore areas. Researchers identified the area extending a distance of about 1 kilometer (0.6 miles) from the shore as the area of greatest use by fish and birds. This area is used primarily by waterbirds, including those that feed on fish and invertebrates. The open water functions by providing area and substrate for fish and invertebrate production. Birds use open water for loafing, foraging, rafting, and as a staging area prior to migration. Open water also provides birds with protection from most predators and human disturbance. Some species, such as eared grebe, rely on open water almost exclusively during their stay at the Salton Sea, while others (e.g., waterfowl, gulls, and pelicans) use open water for a portion of their daily or seasonal activities. Until recently, these areas also provided important habitat for pelagic spawners, such as orangemouth corvina.

Most of the open water areas of the Salton Sea are subject to periodic events that can make large portions of the Salton Sea lethal or uninhabitable to most aquatic life. During parts of the year, the Salton Sea becomes stratified with cooler water forming a distinct layer below the warmer surface water. This lower layer becomes anoxic (deprived of oxygen) because of its isolation from the surface and the decomposition of algae that settle from the overlying surface water. The combination of high levels of organic matter and microbiological activity in this lower water layer and sediments under anoxic conditions produce toxic compounds, such as hydrogen sulfide, that are periodically released to the surface waters when the stratification breaks down during high winds and seasonal changes in temperature. During these turnover events, aquatic life (including fish) can be destroyed over vast areas of the Salton Sea. The effect of these events is less pronounced in the near shore areas that remain oxygenated year round.

River Mouths and Deltas

The river mouths and deltas are defined as the interface between the saline waters of the Salton Sea and the relatively fresh inflows from the rivers and drains, particularly where the New, Alamo, and Whitewater rivers meet the Salton Sea. The size of these areas is influenced primarily by the amount of inflow. The New and Alamo rivers, which constitute nearly 80 percent of the inflow to the Salton Sea, contribute to the largest of these areas. Factors such as depth, inflow quality, and wind conditions also influence the environmental conditions at the river mouths/delta. Sediment deposition in these areas forms deltas that contribute to the complexity and diversity of the habitat. Similar conditions occur at the mouth of the Whitewater River and, to a lesser extent, the mouths of agricultural drains that discharge directly to the Sea.

The river mouths, particularly in the southern part of the Salton Sea, provide an area of reduced salinity and higher dissolved oxygen. Fish species that use these areas also use open water and shallow water near the shoreline. In low salinity to freshwater areas, tilapia, molly, longjaw mudsucker, and other freshwater species are present. Desert pupfish inhabit the lower portions of drains below barriers but have not been observed in the rivers (Sutton, 1999). Orangemouth corvina were reported congregating (possibly for spawning) where freshwater flows into the Salton Sea, possibly due to higher dissolved oxygen or better water quality (Costa-Pierce, 2001).

The river mouths and deltas are relatively small, yet very productive. While these areas are not used exclusively by any one species, they routinely support higher concentrations of birds than surrounding areas. Bird species that use these areas also use open water and shallow water near the shoreline. The higher use by fish and birds relative to other areas likely is attributable to several factors, including:

- A range of salinity that provides conditions that support a more diverse invertebrate community;
- A range of depth, particularly shallow areas accessible to shorebirds, that increases foraging opportunities;
- Higher dissolved oxygen concentrations;
- Availability of fresh water for birds to meet physical and physiological maintenance requirements;
- Concentrations of fish that increase foraging opportunities for fish-eating birds;
- Sediment and nutrient inputs that increase productivity;
- Proximity to the refuge areas (south end);
- Elevated areas (islands) that provide protection from terrestrial predators; and
- Vegetation (primarily on dredge spoils) that supports nesting and roosting structure.

At the river mouths, particularly the New and Alamo rivers, dredging is required to maintain flow to the Salton Sea and prevent water backing up in the rivers upstream. Dredge material is removed from the channel and deposited along the banks. Because of the relatively flat topography on the southern end of the Salton Sea, the channel has been extended well into the Salton Sea in order to convey water and sediment to deeper areas. This dredging creates berms that border the channel and support vegetation, primarily common reed. Vegetation along the berms also supports roosting and nesting by colonial waterbirds. Rooted aquatic plants, such as cattails and sedges, are present at the confluence of the freshwater inflows and the Salton Sea (Bain et al., 1969) where maintenance dredging is infrequent.

The size of the areas influenced by the inflows varies on a daily to seasonal basis in relation to the volume of water discharged to the Salton Sea at each location. Brackish waters ranging from 10,000 to 30,000 mg/L extend about 1,600 to 3,300 feet offshore from the New and Alamo river mouths (Costa-Pierce, 2001), with the larger areas occurring during summer when irrigation runoff is high. The size of the area influenced by the brackish water inflow from the New and Alamo rivers could be about 100 to 250 acres.

Colonial ground nesters/roosters that use the river mouth and delta areas include black skimmer, gull-billed tern, Caspian tern, double-crested cormorant, American white pelican, brown pelican, and California gull. In addition, black-necked stilts use the delta areas for foraging, while Caspian terns roost on mudflats at river mouths. Black skimmers nest at the mouth of the Whitewater River (Patten et al., 2003). Snags and partially submerged utility poles at the river deltas are used as perches and nesting sites for herons, egrets, and double-crested cormorants. Molina and Sturm (2004) found that many colonial waterbirds, especially great blue herons and double-crested cormorants, aggregated at the deltas of the New, Alamo, and Whitewater rivers.

Islands and Snags

Several islands along the margin of the Salton Sea provide important nesting and resting habitat for a variety of birds. With the exception of Mullet Island, these areas are generally very small (few acres or less), devoid of vegetation, and influenced by water surface elevation. Mullet Island, located in the southeastern part of the Salton Sea, has an area of about 11 acres (Molina, 2004) and supports nesting black skimmers, double-crested cormorants, gull-billed terns, Caspian terns, and gulls. About 4,000 double-crested cormorants nested on the island in 1999 (Shuford et al., 2000). Recent observations by Service refuge personnel documented that these areas remain important for cormorants. Partially submerged levees also provide isolated land for bird resting and nesting. Molina (2004) observed that during 1991 through 2001, many gulls, terns, and black skimmers used small islands (islets) at the Salton Sea. Islands are critically important at the Salton Sea and their limited availability possibly limits reproduction by some bird species.

In some areas along the Salton Sea, trees killed by inundation from past increases in the water elevation remain in shallow water along the shoreline. These snags provide important roosting and nesting opportunities for herons, egrets, and other birds. These structures are not permanent, and they continue to degrade and collapse over time. Other structures situated in inundated areas also provide a similar function. Herons, egrets, and double-crested cormorants nest in snags, and some species use partially submerged utility poles surrounded by water (Patten et al., 2003). Most of the snags are located in the Whitewater River delta, near the Wister Unit of the Imperial Wildlife Area, and at Morton Bay. Figure H1-1 provides an overview of on-water or nearshore habitats or habitat features used by birds around the Salton Sea, with special focus on roosting and nesting sites (University of Redlands, 1999).

Reduction of the water surface elevations along the southern shoreline would adversely affect Mullet Island and the bird species that rely on isolated habitat for nesting. Engineering considerations need to be given to keeping existing islands or constructing replacement islands that would provide the same ecological benefits. Molina (2004) recommended that additional nesting areas should be constructed at the Salton Sea. These new nesting sites should be areas completely isolated by water to reduce disturbance to nesting birds. The location of the islands should be near the shoreline or within impoundments near the shore to facilitate foraging in the nearshore water (Molina, 2004).

Freshwater Marsh

In the Salton Sea Basin, freshwater marsh is represented primarily by areas constructed and managed for waterfowl, although it provides substantial benefit to other wildlife such as shorebirds, waterbirds, and Yuma clapper rail. Depending on the goals of the managing entity, these marshes are flooded perennially or seasonally, and support vegetative communities ranging from no vegetation to areas supporting cattails, tules, or other aquatic vegetation interspersed with areas of open water and islets. Unmanaged freshwater marshes occur in various areas around the Salton Sea, primarily where agricultural drain water forms backwater areas before flowing into the Salton Sea. Unmanaged freshwater wetlands also form in areas along some of the canals where seepage occurs.

Managed marsh areas adjacent to the Salton Sea include portions of the existing wildlife refuges and duck clubs (Figure H1-2). While marsh areas are essential components of the refuge systems, the refuges also include adjacent uplands that are managed primarily to provide forage for birds and to provide habitat for other wildlife species.

Two refuge systems are associated with the Salton Sea. The Imperial Wildlife Area is managed by the DFG, and the Sonny Bono Salton Sea National Wildlife Refuge is managed by the Service (Figure H1-3). Both refuges were established to provide winter habitat for migratory waterfowl, in addition to being managed to provide habitat for a wide diversity of resident and migratory wildlife. The operations of the existing managed marshes are constrained by the availability of fresh water.

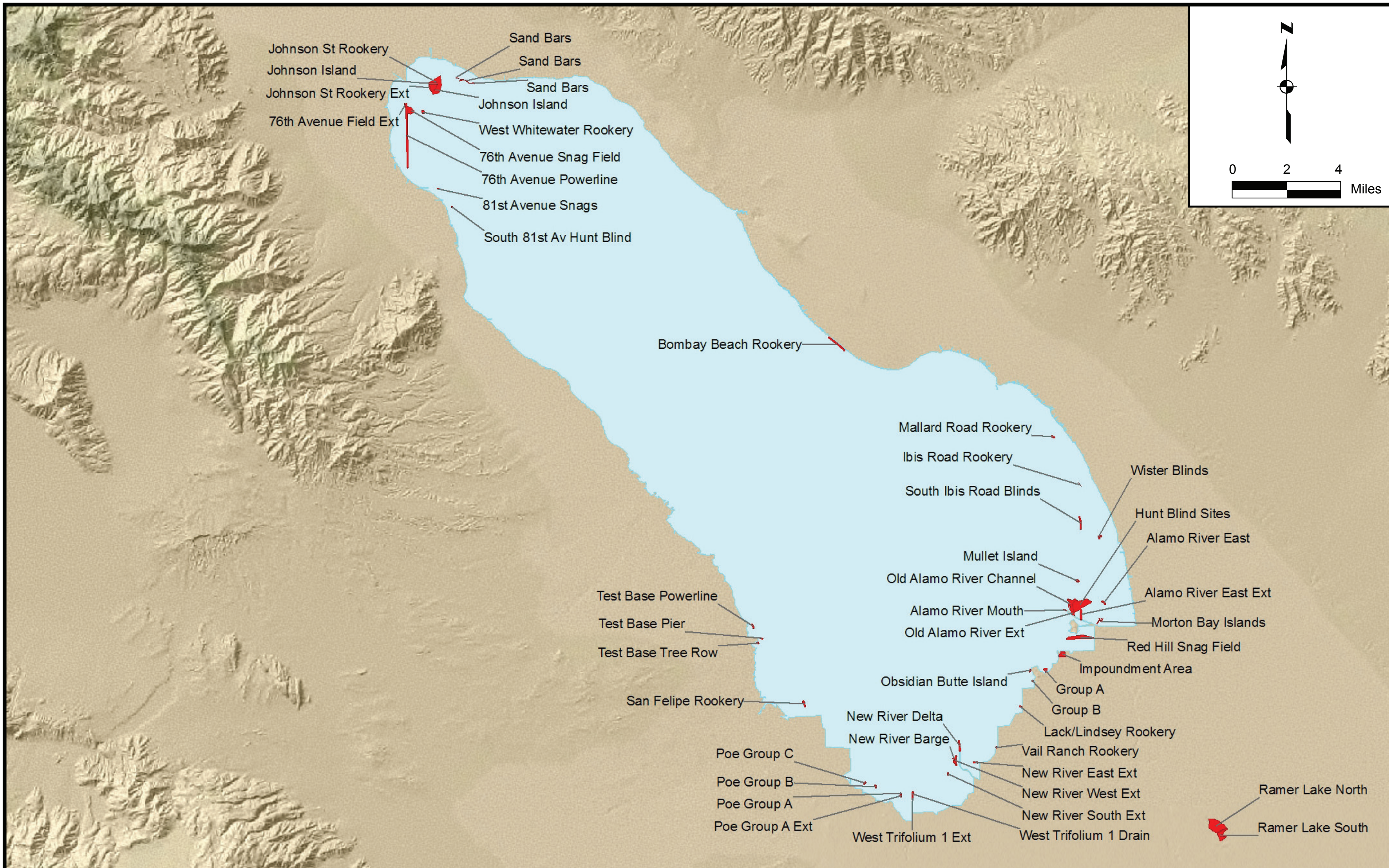
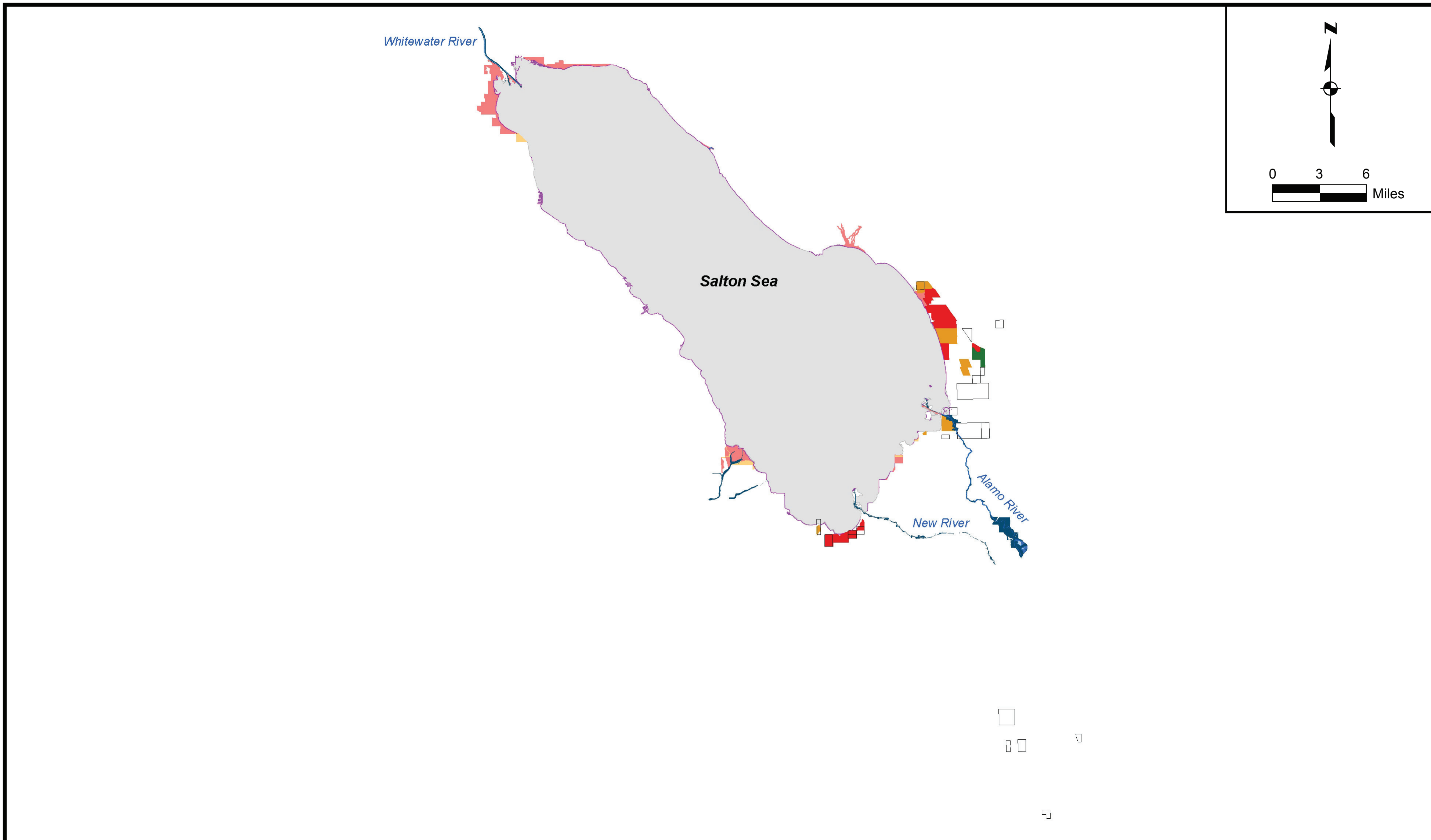


FIGURE H1-1
LOCATION OF SNAG FIELDS AND ISLANDS AT THE SALTON SEA



LEGEND

Adjacent Wetlands	Managed Wetlands	
		Alamo River (classed as a Riparian wetland type)
Scirpus robustus	Scirpus robustus	Riparian Wetland
Tamarix ramosissima	Tamarix ramosissima	Salt Creek (classed as a Riparian wetland type)
Typha latifolia	Typha latifolia	Shoreline strand
	Duck Clubs	Whitewater River (classed as a Riparian wetland)

FIGURE H1-2
LOCATION OF ADJACENT AND MANAGED WETLANDS AT THE SALTON SEA

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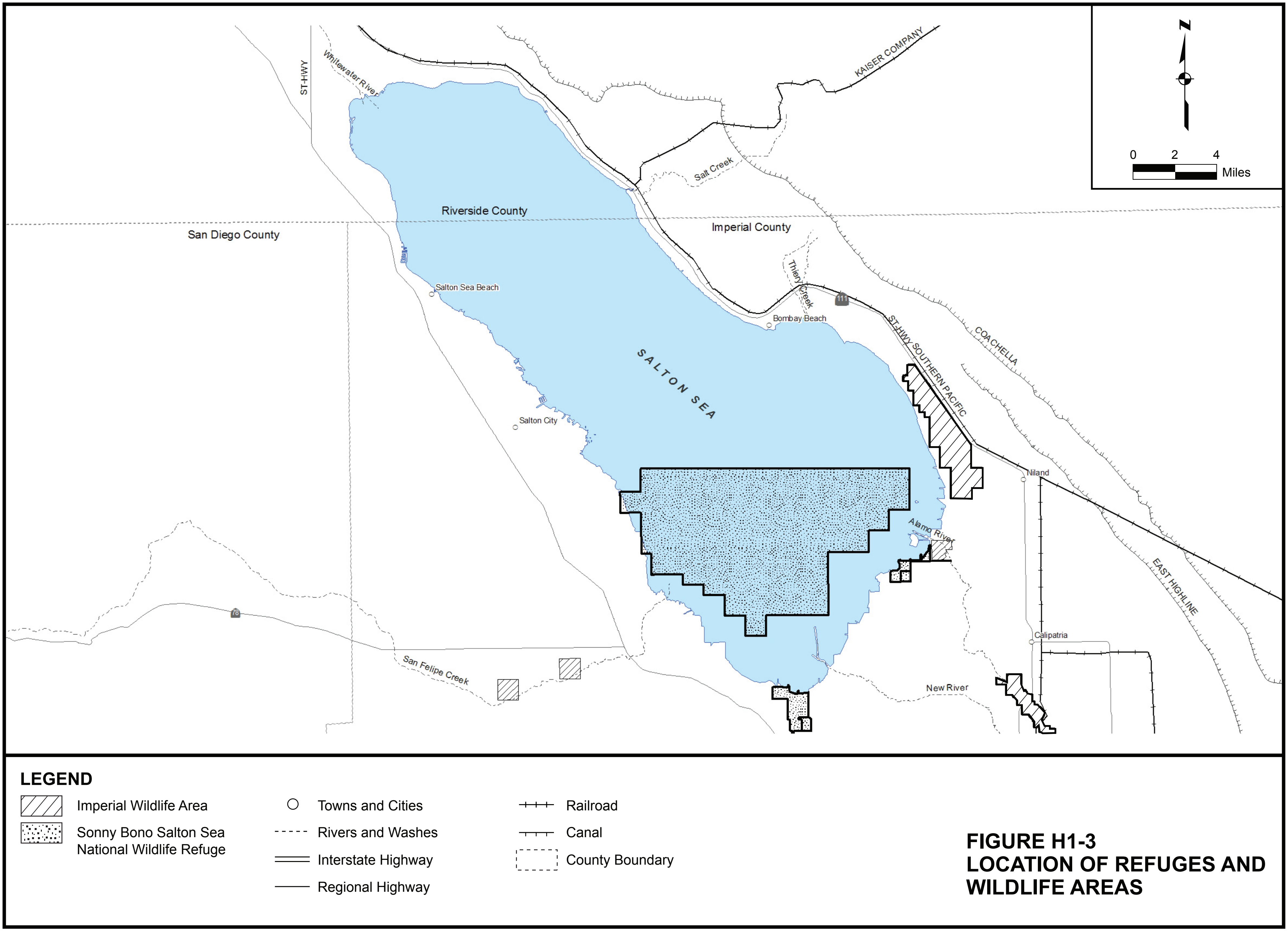


FIGURE H1-3
LOCATION OF REFUGES AND WILDLIFE AREAS

The Imperial Wildlife Area encompasses about 7,930 acres that includes freshwater ponds, desert scrub, canals, and levees (DFG, 2004). It is composed of three units: the Wister Unit (5,883 acres) adjacent to the southeastern shoreline of the Salton Sea, the Finney-Ramer Unit (2,047 acres) in the Imperial Valley between Calipatria and Brawley, and the Hazard Unit (535 acres) along the southeastern portion of the Salton Sea. The Hazard Unit is managed by the Sonny Bono Salton Sea NWR.

The Sonny Bono Salton Sea NWR was established as a sanctuary and breeding ground for birds and wildlife in 1930. Originally, it included about 37,600 acres. Nearly 60 percent of the original acreage was open saline water of the Salton Sea, with the remainder composed of shoreline alkali flats, freshwater wetlands, native desert scrub, and agricultural crop land. Due to the rise in elevation of the Salton Sea, nearly all of the original refuge area has been inundated. Presently, the NWR contains about 850 acres of freshwater marsh (C. Schoneman, 2006).

The managed marshes are designed and managed primarily for waterfowl use. While the managed marshes support large numbers of waterfowl, specific units within the marshes are also managed to support a variety of sensitive species, particularly the Yuma clapper rail and California black rail. Other species associated with freshwater marsh include least bittern, common moorhen, northern harrier, marsh wren, and red-winged black bird. Species that breed in the freshwater marshes include pied-billed grebe, American coot, common moorhen, Yuma clapper rail, marsh wren, common yellowthroat, song sparrow, blue grosbeak, red-wing blackbird, and yellow-headed blackbird (Patten et al., 2003). About half of the population of ruddy ducks on the Pacific Flyway use the open waters of the Salton Sea during the winter and many may breed in marsh areas and at the mouths of rivers at the Salton Sea. Snow and Ross’s geese winter at the refuges, resting on impoundments in the refuge and foraging in alfalfa and grain fields (Patten et al., 2003).

In addition to the freshwater marsh supported by the refuges, about 9,731 acres of duck ponds were present in the Imperial Irrigation District service area in 2004 (King, 2005). The duck ponds are generally located in the northern portion of the Imperial Valley between Niland and the Salton Sea. The ponds typically are small and heavily vegetated with aquatic vegetation. These freshwater marsh areas are flooded seasonally to coincide with the waterfowl hunting season and to promote characteristics attractive to waterfowl.

Agricultural Lands

Agricultural land, especially in the Imperial Valley, supports irrigated crops and field conditions that provide one or more life requisites (e.g., foraging, roosting, or breeding) for a variety of birds. The extent to which these species use agricultural fields varies considerably. Species such as mountain plover and burrowing owl occur exclusively in agricultural areas when they are in the Salton Sea Basin and their continued presence in the area could depend on the persistence of agriculture. Other species such as cattle egret, white-faced ibis, and long-billed curlew predominantly use agricultural fields for one or more life requisites, but also use other habitats in the Salton Sea Basin (e.g., mudflats at the Salton Sea).

Birds primarily use agricultural areas in the Imperial and Coachella valleys for foraging. Located on the Pacific Flyway, the Salton Sea Basin is a major migratory stopover and wintering area, and agricultural fields are frequented by many migrants. Of the 68 species regularly using agricultural fields in the Salton Sea Basin, all use agricultural fields for foraging, 22 for roosting, and 12 nest in agricultural areas. The largest numbers occur during winter and migration periods when hundreds of thousands of birds visit the Salton Sea area.

The Sonoran and Mojave Desert regions, in which the Salton Sea Basin is located, play an important role for wintering and migrating black-bellied plovers, wintering mountain plovers, wintering, migrating and breeding black-necked stilts, wintering and migrating greater yellowlegs, migrating and wintering long-billed curlews, and Wilson’s phalarope. As migrants and wintering birds, these species predominantly forage for insects in agricultural fields. Agricultural fields in the Imperial Valley support much of the mountain plover population during winter and may be the most important wintering area for the species (Oring et al., 2005).

Burrowing owls are the primary species that breed in agricultural areas. The Imperial Valley supports a large number of burrowing owls (greater than 10,000 individuals) and is estimated to harbor about 70 percent of the California burrowing owl population (Shuford et al., 1999). Burrowing owls commonly nest in burrows along the banks of irrigation canals and agricultural drains, and forage in and along the edges of agricultural fields for insects and small mammals (Rosenberg and Haley, 2004).

The Imperial Valley supports about 500,000 acres of agricultural land and the Coachella Valley contains about 65,000 acres. The distribution of crop types in the Imperial Valley is presented in Figure H1-4. Not all of the agricultural fields provide habitat and different crop types and field conditions provide habitat for different species. Further, the habitat value of different crop types can vary seasonally with crop development and from day-to-day in response to irrigation practices. As a result, the amount of habitat available for use by each species is substantially less than the total 565,000 acres of agricultural land in the Imperial and Coachella valleys.

During flood irrigation, several crop types attract species such as waterfowl, shorebirds, egrets, and herons that are typically associated with wetlands, shallow water habitats, and mudflats. These species forage on insects and plant matter in flooded fields. When fields are irrigated, the encroaching water flushes insects making them more accessible and species such as white-faced ibis and cattle egrets are often observed following the water's edge as fields are being irrigated.

Several crop types and field conditions mimic barren or short-grass habitats (e.g., plowed fields and grazed fields). Species using these areas are those typically associated with open upland habitats (e.g., mountain plover and burrowing owls). The short, sparse vegetation and disturbed soil conditions may make insects more accessible to foraging birds.

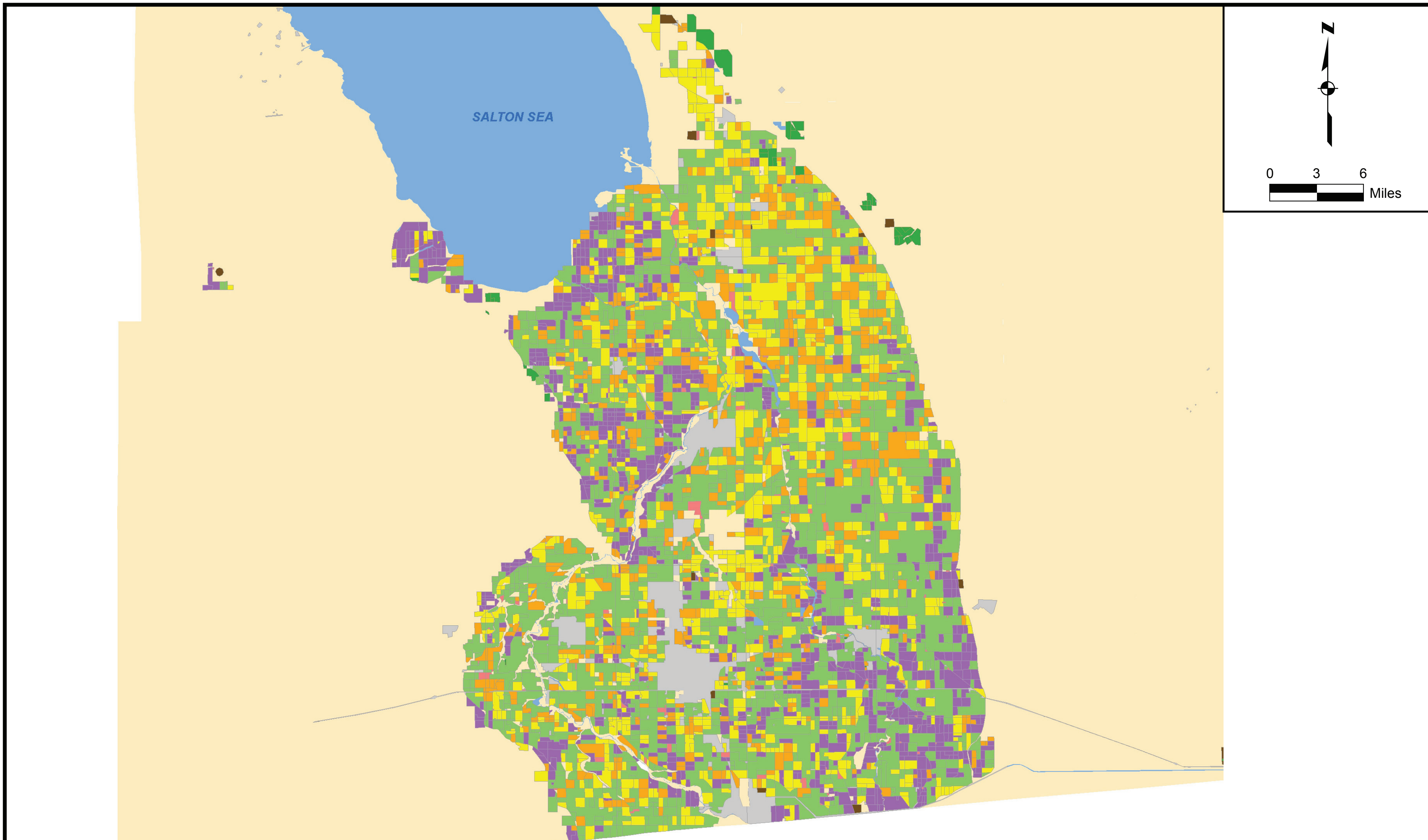
Alfalfa, Bermuda grass, and other grasses are attractive to many species probably because of abundant and diverse prey species (Putnam et al., 2001). Both alfalfa and Bermuda grass are multi-year crops that could allow a greater diversity of insect and small mammals to become established and achieve greater population densities than in annual crops. Alfalfa also could be attractive because of frequent harvest and irrigation. Cutting disturbs insects and small mammals in the field and probably makes prey temporarily more accessible due to reduced vegetation height.

Grains are favored by wintering geese and some ducks because of its high energy content. Wheat, barley, and rye are the principal grain crops in the Imperial Valley. At the Sonny Bono Salton Sea NWR, wheat, rye grass, milo, and millet are farmed to provide habitat for migrating and wintering waterfowl. Grain crops elsewhere in the valley may also be exploited by waterfowl.

FUTURE HABITATS AND FUNCTION

To stabilize conditions and retain habitat values at the Salton Sea and address the objectives under reduced inflows anticipated in the future, restoration options rely primarily on two general approaches: creation and maintenance of a stable, deep marine water body that supports conditions similar to those of the existing Salton Sea and creating a shallower saline habitat that spreads available water over a large area.

This section of the appendix describes habitat characteristics of components that are included in the alternatives. Descriptions of the alternatives are provided in Chapter 3.



LEGEND

1997 DWR Land Use

- Deciduous Fruits and Nuts
- Fallow
- Field Crops
- Grain and Hay Crops
- Native Vegetation/Dryland
- Other
- Pasture
- Truck, Nursery, and Berry Crops
- Urban/Industrial
- Water

FIGURE H1-4
DISTRIBUTION OF AGRICULTURAL CROPS IN THE IMPERIAL VALLEY BASED ON 1997 DWR CROP DATA

The salinity and elevation of the marine water body (referred to as the Marine Sea or Recreational Saltwater Lake), would be stabilized by partitioning the Sea Bed with a barrier. Conditions in the Marine Sea would be maintained by controlling the inflow and creating an outlet that would discharge to the other side of the barrier. Because of the anticipated reduction in future inflow, the Marine Sea would be sized to operate at a reliable flow and would be substantially smaller than the current Salton Sea. Although some of the characteristics of this water body would differ from those in the current Salton Sea, it would be expected to continue to provide shoreline and open water habitat similar to recent conditions in the Salton Sea.

In consideration of reduced future inflows, the alternatives also attempt to replace lost habitat values by creating habitat that requires less water than a stable Marine Sea. While a Marine Sea provides considerable habitat value, researchers suggest that most of those values are concentrated in the shallower water near the shoreline. Shallow water habitat created on exposed Sea Bed as the Salton Sea recedes could mimic the values of the near shore areas and distribute them over a greater area, thus providing greater habitat value per volume of water used. The term Saline Habitat Complex was developed as part of the restoration planning process to define a created water body that mimics the shallow water areas, including the characteristics necessary to support the diversity of fish and wildlife that use the Salton Sea. To be effective, the created habitat must be capable of supporting the important habitat functions previously provided by the Salton Sea.

Large concentric water bodies constructed parallel to the shoreline are components of two alternatives. These water bodies would have many of the same characteristics as Saline Habitat Complex, including depth and the ability to incorporate complexity into the design. They would be linear features as opposed to individual cells that would comprise Saline Habitat Complex.

While the Marine Sea and Saline Habitat Complex are the primary habitat components of restoration and would be expected to make the largest contribution to providing habitat value, other features and water bodies necessary to supply water to these components also provide habitat. These include shallow waterways constructed to serve the purpose of conveying water from the inflow source (rivers and drains) to the other habitat areas, the remnant Salton Sea (referred to as the Brine Sink), and various conveyance channels and facilities. All but the Brine Sink would be expected to provide stable habitat values over time through ongoing operations and maintenance. However, the Brine Sink, which is in essence the Salton Sea once it begins to receive high salinity discharge from either a Marine Sea or Saline Habitat Complex, would diminish in value over time as its size decreases and salinity increases. It would occupy the lowest elevation in the basin and continue to provide some habitat value as long as conditions remain suitable for invertebrate production.

Collectively, these water bodies and features provide habitat intended to retain and replace the habitat values of the Salton Sea. The following describes the characteristics of each of these water bodies, the preliminary design criteria and assumptions used to develop the habitat components of the alternatives, and their justification.

Saline Habitat Complex

The Salton Sea historically provided a range of depths, substrates, and salinities which supported a somewhat limited introduced community of fishes and invertebrates. These communities were notably simple, yet the Salton Sea was phenomenally productive. The Saline Habitat Complex is intended to provide a diversity of habitats to support food web organisms (e.g., invertebrate and fish), which in turn would provide an avian forage base similar to that which developed at the Salton Sea.

The Saline Habitat Complex would blend the higher salinity water of the Marine Sea or Brine Sink with the relatively fresh inflows of the rivers and drains to create a broad salinity range that would encourage invertebrate diversity and foraging opportunities for shorebirds and waterbirds. Salinity within the Saline

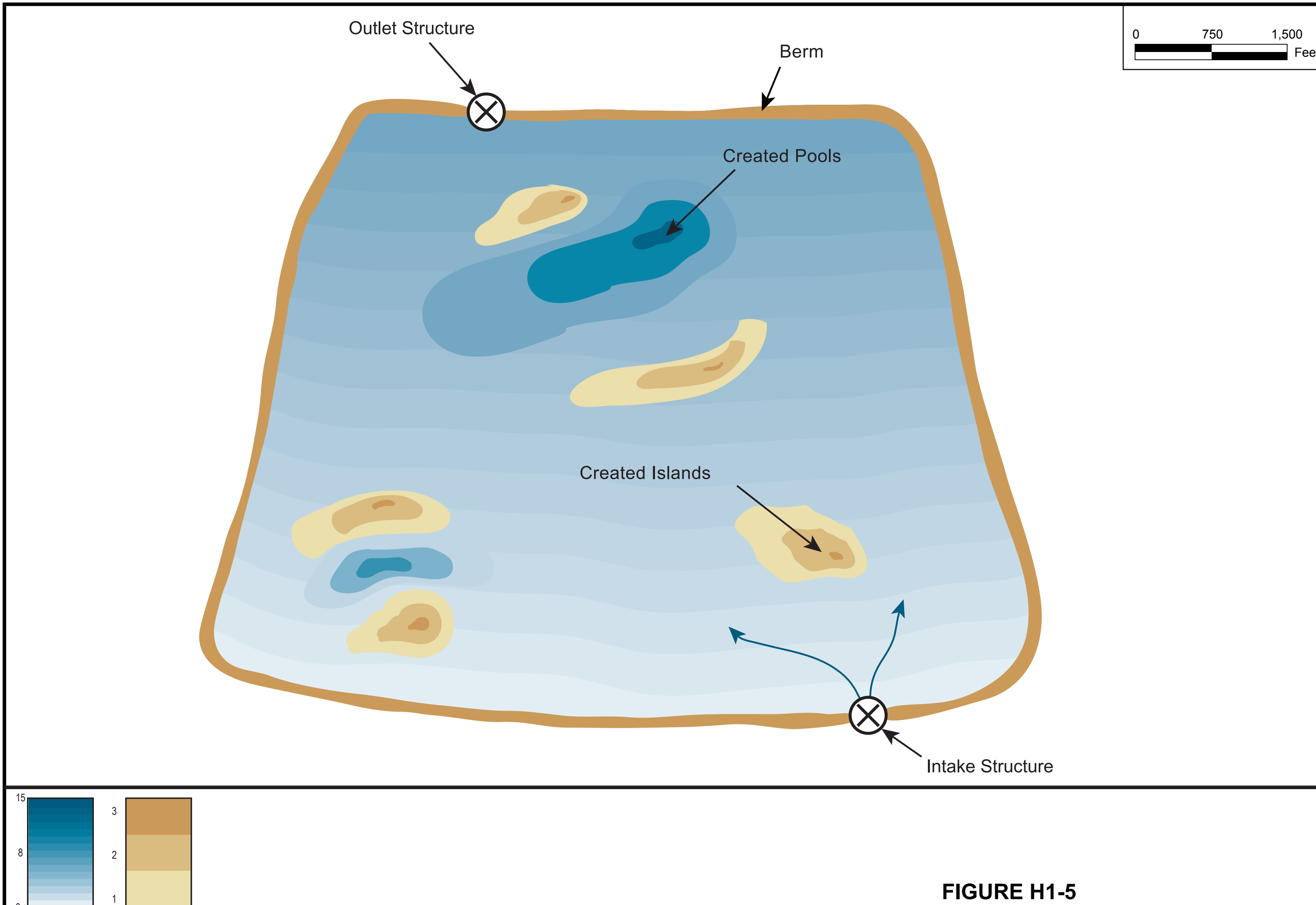
Habitat Complex could range from near 20,000 mg/L to 200,000 mg/L or more. Maintaining most of the Saline Habitat Complex with saline water (greater than 20,000 mg/L) would reduce vegetation growth and help to control vector populations. Depth in the Saline Habitat Complex would be up to 15 feet in some areas, with most of the area covered by shallower water to enhance foraging opportunities for birds. Fish would be an important component of the Saline Habitat Complex, and topographic complexity (variable depths) within the cells would provide them with refuge and cover, and the opportunity to seek suitable conditions. While the composition of the future fish community is uncertain, tilapia likely would be a major component.

While progress has been made toward developing an understanding of the dynamics of the Salton Sea and how it functions to support fish and wildlife, considerable uncertainty remains. In the project-level analyses, the Saline Habitat Complex would be designed to be adaptable and flexible over time. In addition, the Saline Habitat Complex would be constructed in phases that allow the opportunity to monitor and test performance before designing and implementing subsequent phases. This flexibility would be important in correcting unexpected problems that could develop and adjusting to changes in management objectives, new information, or species needs that could occur over time.

Characteristics of the Saline Habitat Complex

Constructed habitat features associated with the Saline Habitat Complex include variable water depths and salinity levels, Berms, islands, and snags. Irregular edges and bottom slope at and adjacent to the water-shoreline interface will contribute to use by shorebirds and wading birds of different sizes. These physical features also would enhance the value of the Saline Habitat Complex by providing foraging, nesting, and roosting opportunities for a variety of avian species. Variable substrates would be provided, including some hard substrates (rock) to support attachment and production of certain invertebrates (barnacles) and algae.

Saline Habitat Complex is characterized by a series of low berms created along the Salton Sea shoreline at about every 6 foot decrease in elevation. The design of the individual cells within the Saline Habitat Complex would be flexible and developed to accommodate the specific needs of the fish and wildlife they are designed to support. These designs could be modified (e.g., water quality management and habitat features) in the future to respond to environmental changes or the results of performance monitoring. For the purpose of evaluating the Saline Habitat Complex at a programmatic level, three conceptual cell types were developed (Figures H1-5 to H1-10). In the conceptual design, each cell would be about 1,000 acres. It is assumed that individual cells designed to accommodate different biological communities would be constructed in tandem to provide a greater diversity of adjacent/connecting habitats (Figure H1-11). The characteristics that would vary among cells likely would include salinity, overall water depth of the cell, presence or absence of islands and deep pools, number and arrangement of roosting and nesting structures (e.g., artificial snags), amount of shoreline, presence or absence of hard substrates, and bottom slope. The specific types of cells (ratio of water to land), the salinity within the cell, and the arrangement of the cells would be developed in the project-level analyses. In each of the Saline Habitat Complex cells, management actions would maintain or control salinity within ranges necessary to maintain aquatic habitat and aquatic organisms as a suitable forage base for birds. Water would flow through the habitat areas to control salinity, flowing from one habitat cell potentially into a series of increasingly more saline habitat cells before being discharged into the Brine Sink. Descriptions of the three conceptual cell types for the Saline Habitat Complex follow. These conceptual designs are intended to describe the range of cell conditions that might be created through restoration.



Note: Each cell is about 1,000 acres. Average depth is about 5 feet. Pool depth is up to 15 feet.

FIGURE H1-5
TYPE 1 SALINE HABITAT COMPLEX

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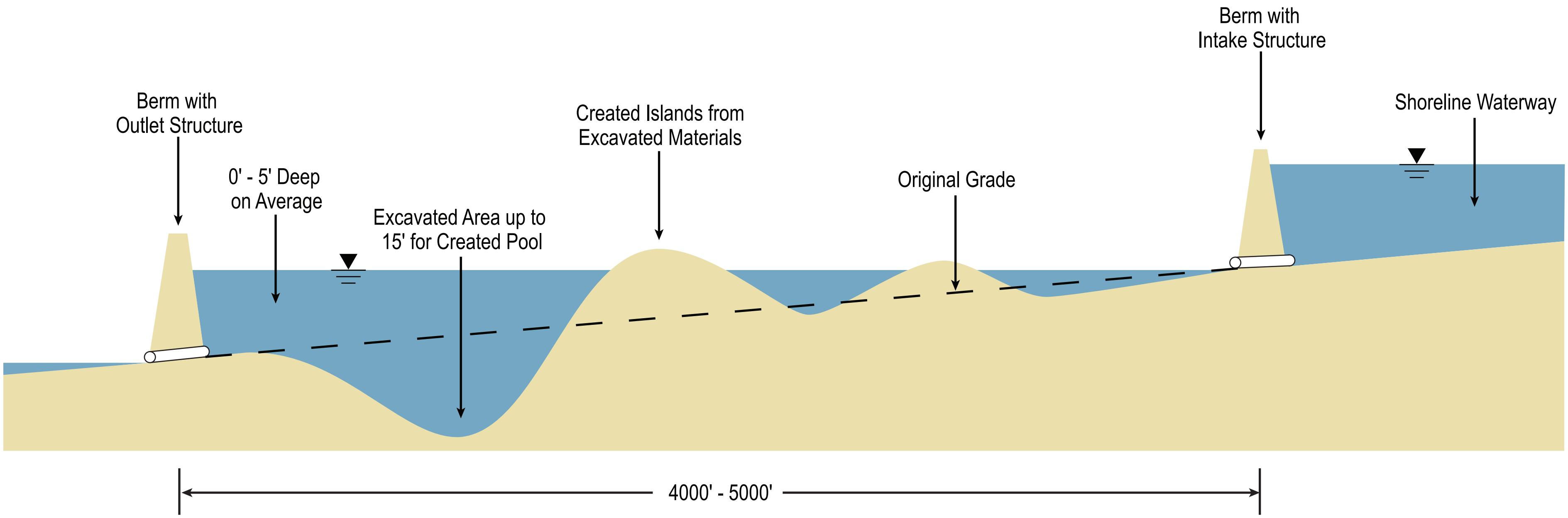
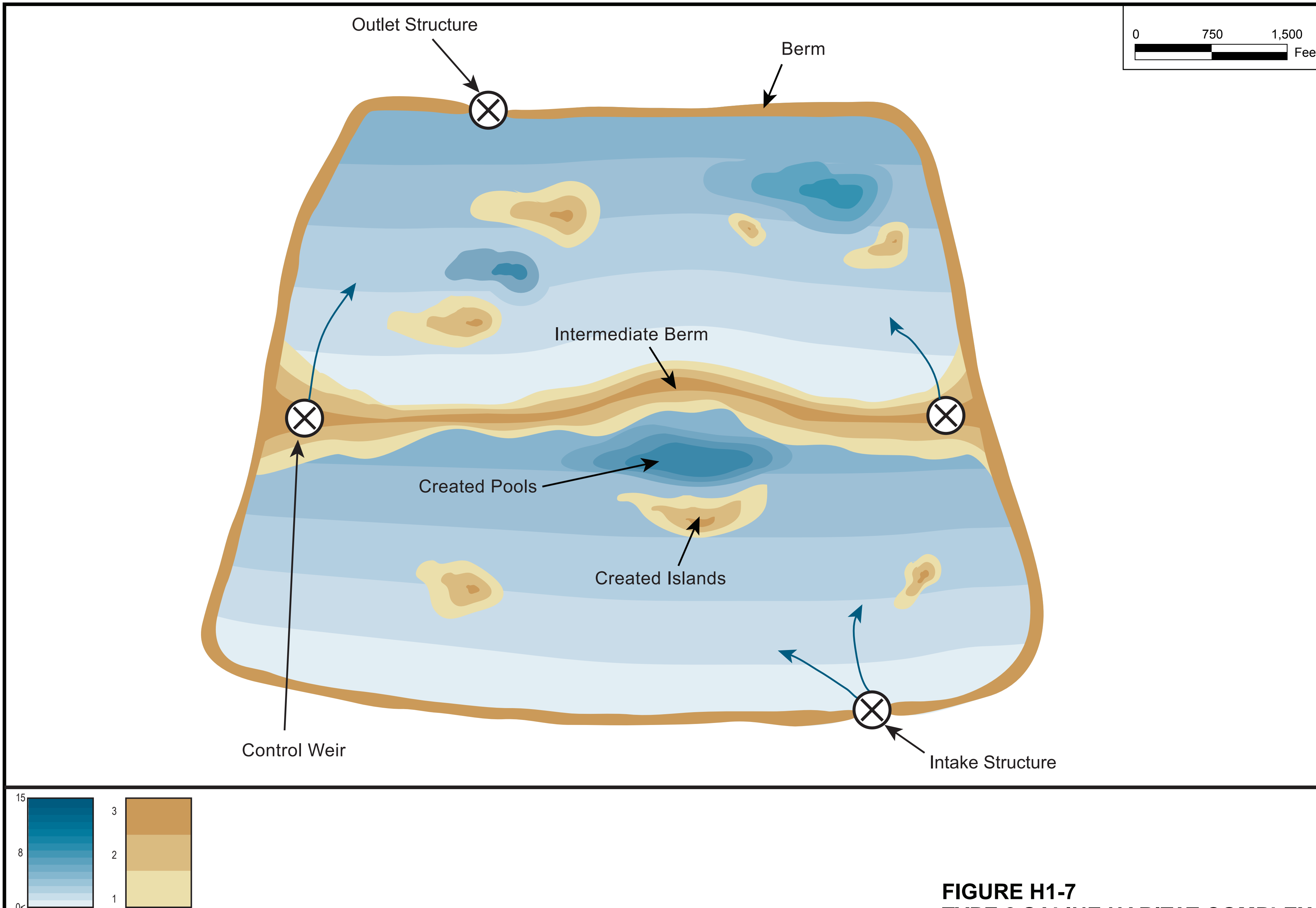


FIGURE H1-6
EXAMPLE PROFILE OF TYPE 1
SALINE HABITAT COMPLEX



Note: Each cell is about 1,000 acres. Average depth is about 3 feet. Pool depth is up to 10 feet.

FIGURE H1-7
TYPE 2 SALINE HABITAT COMPLEX

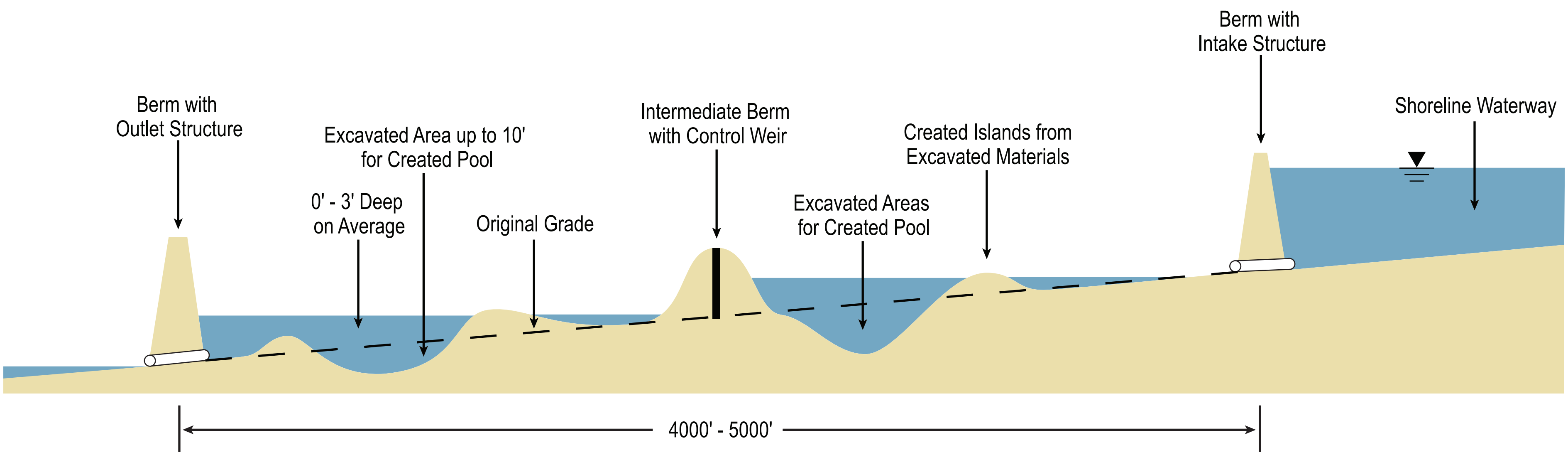


FIGURE H1-8
EXAMPLE PROFILE OF TYPE 2
SALINE HABITAT COMPLEX

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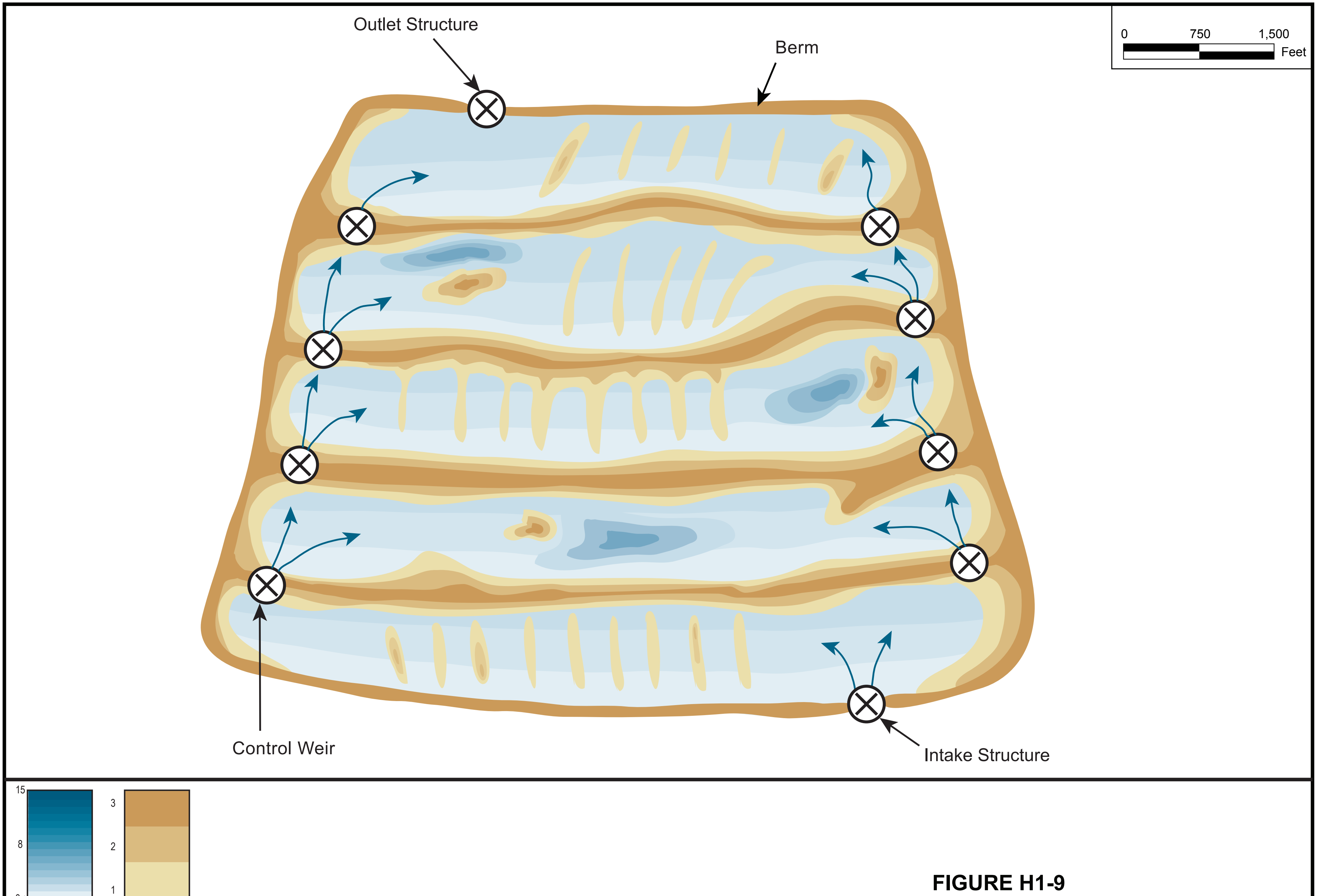

Note: Each cell is about 1,000 acres. Average depth is about 1 foot. Pool depth is up to 5 feet.

FIGURE H1-9
TYPE 3 SALINE HABITAT COMPLEX

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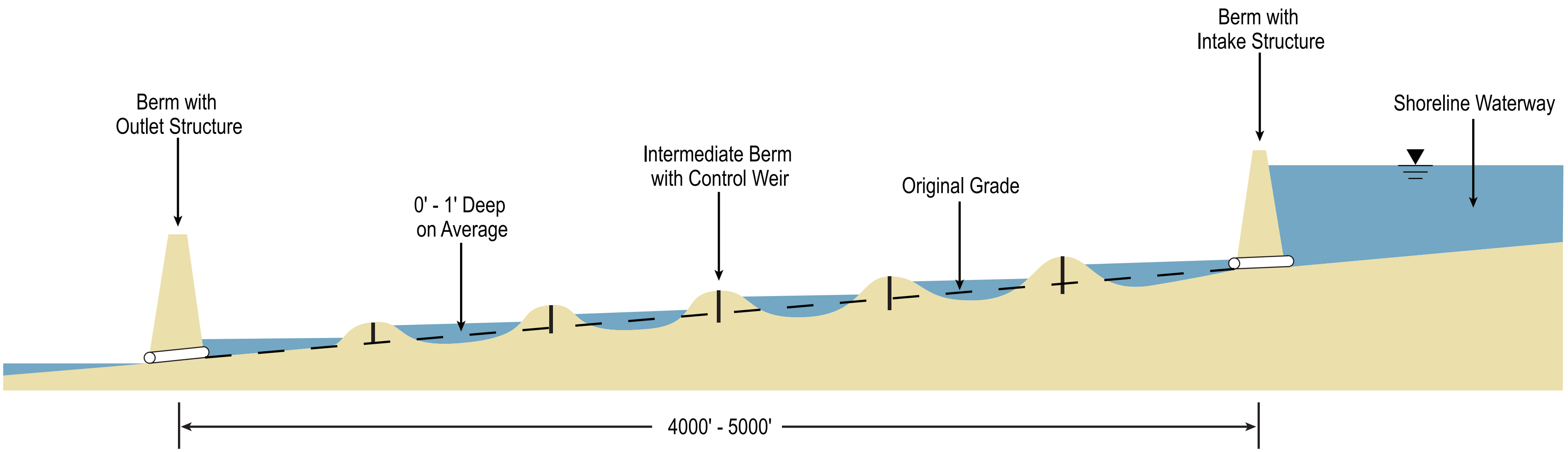

FIGURE H1-10
EXAMPLE PROFILE OF TYPE 3
SALINE HABITAT COMPLEX

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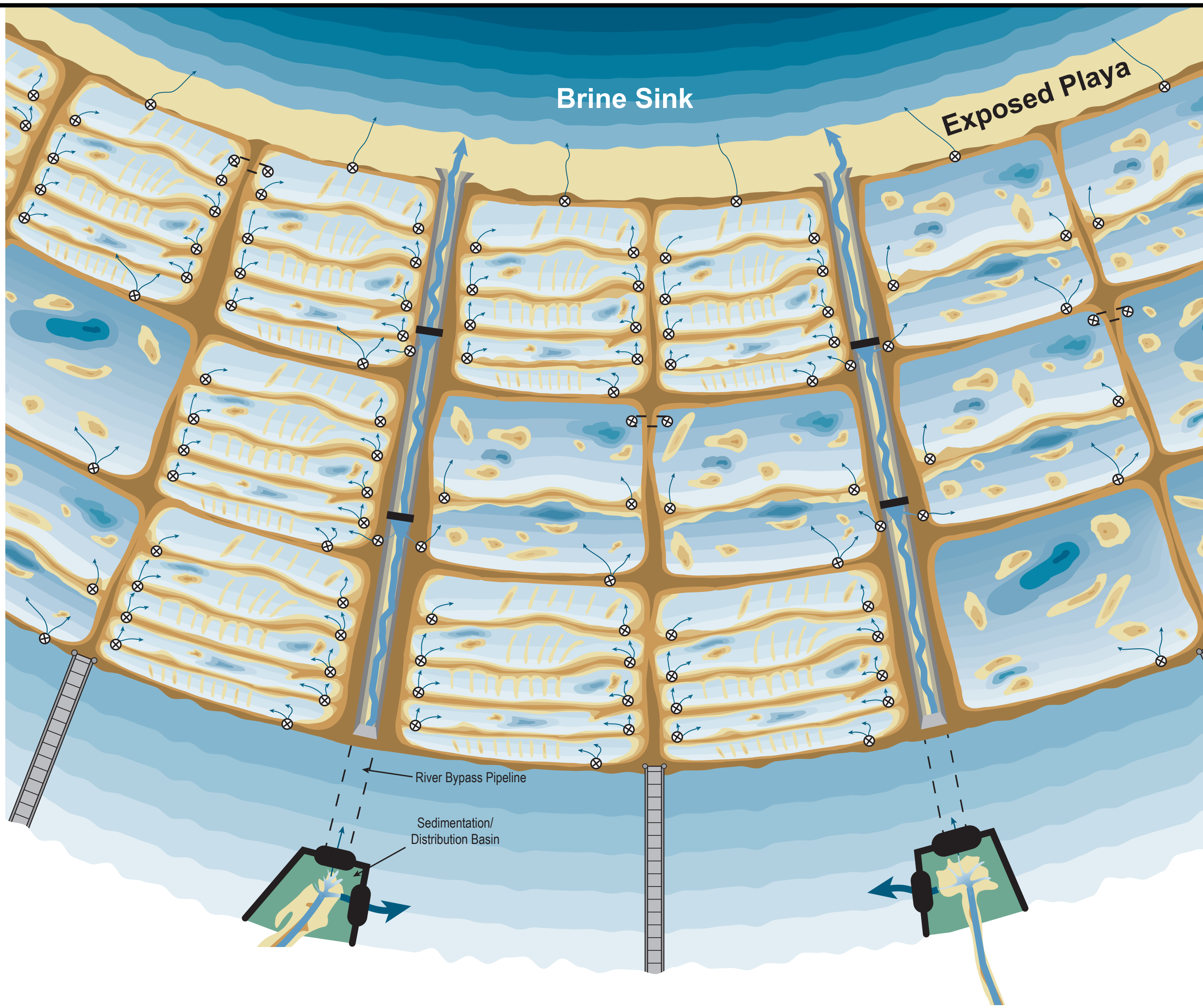

FIGURE H1-11
CONCEPTUAL LAYOUT OF TYPE 1, 2, AND 3 SALINE HABITAT COMPLEX CELLS

Type 1 Saline Habitat Complex

Overall, Type 1 Saline Habitat Complex is an open water cell with constructed features such as islands and excavated deeper water areas (Figures H1-5 and H1-6). About 90 percent of the Type 1 cell would be open water and about 10 percent of the area would include Berms and islands. Additional habitat enhancements could include the placement of artificial snags for roosting and nesting birds. Type 1 Saline Habitat Complex would be created by a series of low Berms constructed along the Salton Sea shoreline at about every 6 foot decrease in elevation. The Berms would be relatively low to allow simple construction methods. The construction likely would use the material excavated to form deep areas to construct islands and Berms. The average depth of the Type 1 Saline Habitat Complex cell would be about 5 feet with areas as deep as 15 feet in the pools. Salinity in individual cells would remain relatively constant, with cells ranging in salinity from about 20,000 mg/L to 200,000 mg/L. These cells, however, likely would focus on fish production and target salinity ranges within the tolerance range of the fish inhabiting the cell. The highest salinity levels ultimately would be based on the capability of the cell to continue to support productive invertebrate communities and bird use.

Type 2 Saline Habitat Complex

Overall, Type 2 Saline Habitat Complex typically would contain greater topographic complexity than Type 1 and possibly isolated water bodies within the cell (Figures H1-7 and H1-8). Similar to Type 1 Saline Habitat Complex, this conceptual cell design would be created by a series of low Berms constructed along the shoreline at about every 6 foot decrease in elevation, and would contain an intermediate Berm dividing the cell. The excavation of the pools would provide the material for construction of low islands. The average depth of the Type 2 Saline Habitat Complex cell would be about 3 feet with areas as deep as 10 feet in the pools. About 80 percent of the Type 2 cell would be open water and about 20 percent of the area would include Berms and islands. Salinity of the Type 2 Saline Habitat Complex would range from about 20,000 mg/L to 200,000 mg/L.

Type 3 Saline Habitat Complex

Type 3 Saline Habitat Complex would typically be a cell traversed by multiple intermediate Berms, with constructed features such as created islands and shallow pools (Figures H1-9 and H1-10). Additional, low transverse Berms (or habitat peninsulas) could be constructed at an angle to the intermediate Berms to increase the area for nesting, resting, and foraging. The average depth of the Type 3 Saline Habitat Complex cell would be about 1 foot, with areas as deep as 5 feet in the pools. About 60 percent of the Type 3 cell would be open water and about 40 percent of the area would include Berms and islands. Salinity of the Type 3 Saline Habitat Complex would range from about 20,000 mg/L to 200,000 mg/L.

Layout of the Saline Habitat Complex

The layout of the Saline Habitat Complex would be flexible and could be arranged in a variety of ways to meet specific needs. A conceptual layout of the Saline Habitat Complex is presented in Figure H1-11. The individual cells would function relatively independent of one another and within a stable range of depth and salinity. The specific types of cells (ratio of water to land), salinity within the cell, and arrangement of the cells would be developed in the project-level analyses. It is likely that performance of the initial phase of the Saline Habitat Complex development would be used during development of subsequent phases to improve operations and performance. Initially, it is assumed that, in total, about 75 percent of the total acreage of the Saline Habitat Complex would be managed for salinity levels that would support fish. This proportion reflects the current conditions at the Salton Sea where most of the area used by birds supports fish. Cells with higher salinities, although incapable of supporting fish, would support invertebrates (e.g., brine flies and brine shrimp) and provide foraging opportunities for many birds.

Shoreline Waterway

The Shoreline Waterway is a water body intended to blend and convey water to the Saline Habitat Complex cells. This water body also would extend the Saline Habitat Complex habitat. If the Shoreline Waterway was located along the shoreline, this water body also would provide desert pupfish connectivity. The Shoreline Waterway would be created in a similar manner to Saline Habitat Complex without cell walls or excavated deep holes, and maintained at a salinity of about 20,000 to 30,000 mg/L.

Water Sources

Water for the Saline Habitat Complex cells would be derived from a combination of sources and would be dependent on the location of the created habitats. For example, creation of the Saline Habitat Complex along the southern shoreline would depend on direct inflow from the agricultural drains and the New and Alamo rivers. The Saline Habitat Complex cells could be directly linked to the drains or water could be blended from several sources. For the purposes of the PEIR, it was assumed that drains on the east side of the Salton Sea could provide about 55,000 acre-feet/year, drains in the southeast portion could provide about 27,000 acre-feet/year, and drains in the southwest portion could provide about 15,000 acre-feet/year (Figure H1-12). It was further assumed that the New and Alamo rivers could provide up to about 250,000 acre-feet/year to the Saline Habitat Complex depending upon the alternative. Saltwater could be recirculated from Saline Habitat Complex cells, Marine Sea, or the Brine Sink.

Anticipated Water Quality

The ability of the Saline Habitat Complex to support invertebrates, fish, and birds would be strongly influenced by the water quality in the individual cells. The Salton Sea is highly eutrophic – a condition responsible for both the Salton Sea's high productivity and the periodic conditions that are destructive to fish and wildlife. Because the source of water for the Saline Habitat Complex would be largely the same as for the Salton Sea, the water quality dynamics that have influenced habitat quality in the Salton Sea could similarly affect the habitat quality in the Saline Habitat Complex. In addition to the influent water quality (nutrients, salinity, etc.), flow-through characteristics, cell size and depth, and characteristics of the wind field would contribute to the overall quality of the habitat.

The Saline Habitat Complex cells are likely to support production of algae, invertebrates, and fish with little potential for water quality degradation (dissolved oxygen depletion, hydrogen sulfide production). The frequent and significant winds combined with the open fetch and shallow depth of the cells will support a freely mixed environment that will mitigate for potential problems associated with eutrophic or hypereutrophic conditions. However, because of the high nutrient levels and productivity in the cells, periods of very low dissolved oxygen levels likely would occur during the early morning hours prior to sunrise with increased dissolved oxygen levels during the day due to oxygen generation through photosynthesis. The shallow cells less than 6 feet deep will experience the greatest temperature extremes but should maintain adequate dissolved oxygen to support fish. Anticipated water quality conditions are described in greater detail below.

Salinity

Cells within the Saline Habitat Complex would be designed to maintain salinities ranging from 20,000 mg/L to 200,000 mg/L or higher. Optimal salinity levels ultimately will be determined from information gathered through monitoring and adaptive management during the first stages of Saline Habitat Complex development. Cells would be maintained within the salinity range determined to support productive invertebrate and bird use. Water exceeding this salinity range would be discharged to the Brine Sink. A minimum salinity of 20,000 mg/L would be maintained for the purpose of reducing or preventing encroachment by rooted vegetation and reducing vectors (e.g., mosquitoes).

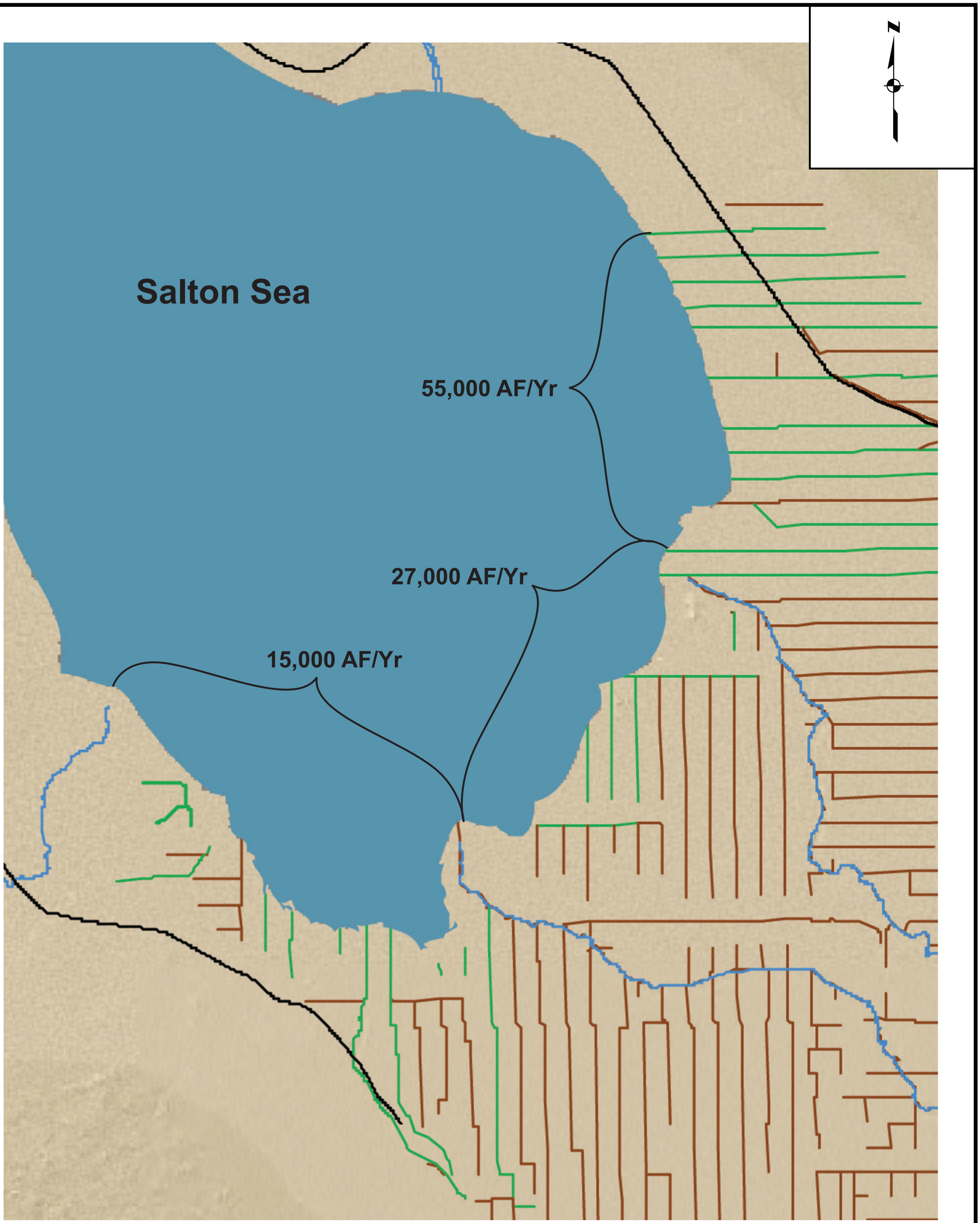

FIGURE H1-12
DISTRIBUTION AND RELATIVE INFLOW OF AGRICULTURAL DRAINS DISCHARGING TO THE SALTON SEA

Water Temperature

One important factor affecting the potential quality of the Saline Habitat Complex for aquatic organisms would be the water temperature within the cells. Most organisms have a distinct range of temperatures within which they can survive and reproduce, with preferred or optimal conditions towards the middle of the range. Exposure to water temperatures outside of their optimal range could result in moderate to acute stress on individuals, and prolonged exposure to sublethal water temperatures could result in impairment. Even brief exposure to water temperatures above an organism's thermal tolerance could lead to mortality.

To evaluate the potential for water temperatures to adversely affect the quality of habitat in the Saline Habitat Complex, a one-dimensional model using Salton Sea wind data (averaged from three stations and adjusted for open sea conditions) and local temperatures was developed (Appendix D). For modeling purposes, the Saline Habitat Complex was characterized as a 6 foot deep cell with a 1-mile wind fetch, located at the south end of the Salton Sea. Based on the model results, the frequent and significant winds combined with the open fetch and shallow depth of the cells would support a freely mixed environment in the Saline Habitat Complex cells. Results from the modeling indicated water temperatures at the mid-point of the water column in the 6 foot-deep cells likely would range from 48 to 91 degrees Fahrenheit (°F) (8.9 to 32.8 degrees Celsius [°C]). For comparison, predicted surface (less than 6 feet deep) water temperatures in the Salton Sea would range from 54.5 to 86 °F (12.5 to 30 °C) under the same conditions. To account for interruption of wind fetch by habitat islands and other features associated with the Saline Habitat Complex, or periods with little wind, the same analysis was conducted using a lower wind speed of 1.1 miles/hour (0.5 meters/second). For perspective, the average wind speed on the south end of the Salton Sea in 1999 was 8.5 miles/hour (3.82 meters/second). Based on this analysis, predicted water temperatures within the 6 foot-deep cells would range from 54 to 97 °F (12.2 to 36.1 °C). Figure H1-13 illustrates the range of temperatures predicted in the Saline Habitat Complex and Salton Sea based on model results. The coolest water temperatures are predicted to occur during the late-fall and winter months.

Selenium

Another important factor affecting organisms inhabiting the Salton Sea is selenium. Selenium is a naturally occurring element found in rocks and soils. Selenium is persistent in the environment, changing chemical forms and moving from one medium to another, but it does not degrade in the sense of organic chemicals. Biogeochemical processes cause cycling from abiotic media to biotic media, and back to abiotic media, but it does not disappear. Thus, it is important to consider this persistence in relation to water, sediment, and biota within the Salton Sea. Bioaccumulation is the combined net accumulation of a chemical from abiotic media and ingestion of chemical-containing biota. Selenium can bioaccumulate in both aquatic and terrestrial food webs, including higher trophic-level animals that feed on those plants and animals.

Selenium can be transported via rivers, streams, creeks, and irrigation drainage water. Most of the selenium at the Salton Sea is transported in irrigation water diverted from the lower Colorado River. Terminal water bodies such as the Salton Sea may become contaminated due to evaporative enrichment and concentration in agricultural fields over several seasons of runoff. In an aquatic system like the Salton Sea, selenium is generally associated with sediments (acting as a sink and reservoir) or plants and animals. Most of the selenium found at the Salton Sea is located within anoxic sediments in the deeper portions of the Salton Sea where the selenium is relatively unavailable to biota because of low exposure rates (USGS, 2003). Modifications to the Salton Sea that would decrease water depth and increase oxidation of the deep sediments would tend to increase overall selenium bioavailability. If exposed sediments around the Salton Sea shoreline (as a result of falling water levels) undergo frequent wetting and drying cycles or if shallow water is ponded (as in the Saline Habitat Complex), selenium bioavailability in the food chain could be increased in a manner similar to that associated with wetlands and ephemeral pools.

The most important food-web pathway for selenium in the Salton Sea begins with accumulation from sediment by benthic invertebrates, particularly pileworms, and includes subsequent uptake by benthic-feeding fish and fish-eating birds (Setmire et al., 1993). Selenium at the Salton Sea is transferred through successive trophic levels in the food web at increasing concentrations (Setmire et al., 1993). Selenium concentrations in food web organisms of tributary rivers and agricultural drains were similar to those for the Salton Sea food webs, but with lower levels at higher trophic levels. Setmire et al. (1993) noted that large birds feeding in rivers do not accumulate nearly as much selenium as those feeding in the Salton Sea. In general, selenium concentrations at the highest freshwater trophic levels were only one-half of those in the Salton Sea.

To evaluate the potential for adverse effects due to selenium in the Saline Habitat Complex, an ecological risk assessment was conducted. Each of the habitats was evaluated as though the selenium exposures were uniform throughout the habitat. However, it is expected that waterborne selenium concentrations would vary significantly depending on the location within the Saline Habitat Complex. The selenium concentrations and associated risk in each cell would be a function of 1) the underlying sediment selenium concentrations and 2) how the waterborne selenium distributes throughout the complex. It is expected that waterborne selenium would attenuate significantly within the first one third of the water flow pathway, but this pattern could be altered by water conveyance canals that channel water into different portions of the Saline Habitat Complex (i.e., there is not one single water flow direction within the habitat). Inflow cells of the Saline Habitat Complex would be expected to have potential selenium risks higher than those estimated in the risk assessment (Appendix F). The remaining Saline Habitat Complex areas would be expected to have risks lower than those estimated in the selenium ecological risk assessment.

Dissolved Oxygen

Another important factor potentially affecting the water quality of the Saline Habitat Complex for aquatic organisms would be the dissolved oxygen concentrations. In most nutrient rich aquatic environments, dissolved oxygen levels are depressed by poor circulation and aeration, and the high oxygen demand created by algae and the decomposition of organic material. Re-aeration caused by wind mixing is an important factor in the maintenance of dissolved oxygen levels under conditions of eutrophication. Regarding aeration, two factors can contribute to low levels of dissolved oxygen: stratification due to stable temperature layering and/or the absence of mixing (even in the absence of stratification) due to lack of wind.

Effects on habitat quality from wind-induced mixing in the Saline Habitat Complex were evaluated using the one-dimensional model of the Salton Sea (Appendix D). The model results indicated that a cell would be fully mixed to a depth of about 6 feet throughout the year under baseline (1999) wind conditions. Thus, areas with depths of 6 feet or less within cells in the Saline Habitat Complex would not be expected to thermally stratify at any point during the year. There may be areas within the Saline Habitat Complex that stratify due to their increased depth (excavated holes); however, this should not adversely affect aquatic organisms in the Saline Habitat Complex because most of the cell would remain mixed, with adequate dissolved oxygen for these organisms. Final habitat design that includes islands should make every effort to minimize deleterious effects on mixing (e.g., orientation of islands with the prevailing wind).

Even in the absence of thermal stratification, windless periods could produce partial dissolved oxygen depletion in the deeper areas of the cells, with the severity and importance of the depletion directly related to the time of year and duration of wind-free conditions. The summer is of greatest concern because warmer waters hold less dissolved oxygen and support increased biological activity. In the one-dimensional model of the Salton Sea, a value of 4.5 miles/hour (2 meters/second) was the minimum velocity that would provide mixing to a depth of 6 feet (2 meters). The Salton Sea is relatively windy during the summer months, and the wind velocity information for the Salton Sea area used in the water quality model (1999) indicates only 7 days with average wind speeds less than 4.5 miles/hour during the April through mid-October period (3.5 percent of the total days). It should be noted that those 7 days with low wind velocity had winds near 4.5 miles/hour as a daily average. Model results suggest that the potential for windless periods and diminished mixing are relatively low and that the Saline Habitat Complex cells likely would remain mixed and aerated during the summer.

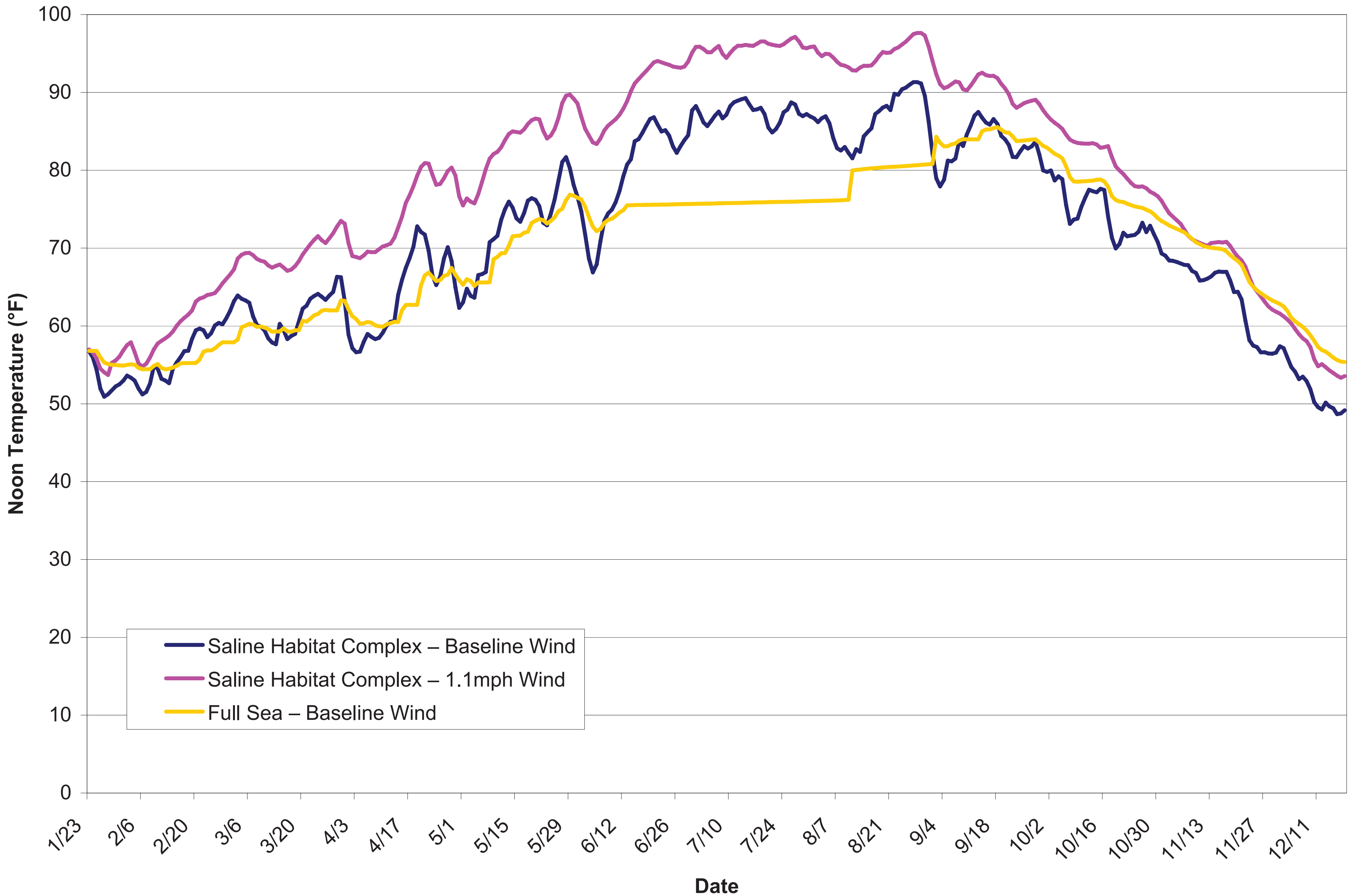

FIGURE H1-13
PREDICTED NOONTIME WATER TEMPERATURES IN 2-METER (~6 FOOT) DEEP SALINE HABITAT COMPLEX CELLS AND AT THE SURFACE OF THE SALTON SEA

Model results suggest the cells would be very eutrophic and algae-rich, with the potential for high oxygen demand and dissolved oxygen depletion during overnight and windless periods. Such cells typically experience a high degree of daily oxygen and pH fluctuations (with lowest pH and dissolved oxygen levels at night) with the potential for fish-killing levels of low dissolved oxygen. Because periods of anoxia are unlikely to persist in the Saline Habitat Complex cells, there would be little potential for ammonia and hydrogen sulfide production.

Nutrients

The shallow and nutrient-rich nature of the Saline Habitat Complex was evaluated independently from the rest of the Salton Sea to characterize water quality and potential of the habitats using an empirical model (Appendix D) that predicted average summer water quality conditions such as chlorophyll concentrations, in-lake phosphorus and nitrogen concentrations, water clarity, and lake Trophic State Index (TSI). The TSI is a single number that incorporates various water quality values on a scale from 1 to 100, where higher values indicate more enriched, eutrophic conditions. The model results confirmed that the Saline Habitat Complex cells and other shallow facilities are likely to be hypereutrophic in character.

Water clarity in the Saline Habitat Complex is expected to be less than one foot, with high chlorophyll values (greater than 0.022 mg/L) and TSI values in the hypereutrophic range (greater than 70) if they are filled with any combination of water from the rivers and drains currently flowing into the Salton Sea. This is consistent with the recent measurements of chlorophyll concentrations in the Salton Sea that exceed 0.01 mg/L.

Biological Characteristics

The modular design of the Saline Habitat Complex would create opportunities for multiple aquatic communities. Design objectives include constructing cells that mimic, to the extent possible, the historic conditions and community associated with the shoreline of the Salton Sea. Many of the species currently found in the Salton Sea and the rivers and drains flowing to the Salton Sea likely would inhabit the Saline Habitat Complex. Other cells would likely contain different communities, but with productivity levels that would support relatively high levels of bird use. Life history attributes and water quality tolerance of species currently found in the Salton Sea and likely to be found in the Saline Habitat Complex are described below.

Invertebrates

The Saline Habitat Complex cells likely would provide biotic and abiotic conditions necessary to support several of the invertebrate species (e.g., pileworms and barnacles) that previously contributed to the productivity of the Salton Sea and its importance to birds. Barnacles and pileworms were not only among the most important benthic invertebrates of the Salton Sea's deep marine habitats, but their free-swimming larval life stages also contributed a major portion of the biomass available for consumption by fish and invertebrate-eating birds. Although these two species would have the potential to occur in many of the Saline Habitat Complex cells, the preponderance of shallow water habitat would probably facilitate community dominance by other macroinvertebrates such as corixids and gammarid shrimp.

Pileworm

Pileworms, which are native to the North Atlantic, have extended their range and are now found on the Atlantic and Pacific coasts in both the northern and southern hemispheres (Pettibone, 1963). Within its range, a wide variety of microhabitat conditions (temperature, dissolved oxygen, salinity, and sediment) are used by pileworms. Detwiler et al. (2002) found pileworms in the Salton Sea on and in algae-covered rocks along the shoreline, barnacle-covered rocks, loose barnacle shell substrates, and offshore sediments consisting of sand, silt, clay, and barnacle shell debris.

As reported in Detwiler et al. (2002), pileworms were the dominant benthic species in 1999; densities were consistently highest at the 2 meter (6 foot) depth stations. This pattern was repeated in 2004 (Dexter et al., 2006). Density declined over the summer; as oxygen content decreased to near zero at the deeper stations and mean water temperatures increased to above 25 °C (77 °F). in July 1999, pileworms were present only at the 2 meter (6 foot) and 4 meter (13 foot) stations. In September 1999, pileworm density was reduced 95 percent relative to July 1999 and pileworms were present only at the 2 meter (6 foot) depth stations (Detwiler et al., 2002). Pileworm biomass was highest in March 1999 with about 6.5 percent found between 0 and 4 meter (0 to 13 feet) depths. The percentage of pileworms found in this depth range increased to 41 percent in May 1999 and 99 percent from July to November 1999 (Detwiler et al., 2002). Although sampling was conducted at discrete locations (stations) within the current Salton Sea, results suggest that pileworms could use the depth ranges anticipated in the Saline Habitat Complex.

Shoreline barnacle substrates were also important habitat areas for juvenile pileworms at the Salton Sea. The structural heterogeneity and vertical relief of the barnacle substrates may provide refugia from predation and intraspecific competition, allowing more pileworms to coexist per unit area than on sand and clay substrates (Detwiler et al., 2002). Saline Habitat Complex cells would be managed to provide a variety of substrates suitable for pileworms.

The temperature tolerance of pileworms is not well known, but the population at the Salton Sea has persisted for many years under highly eutrophic conditions, and a 19 to 21 °C (34 to 38 °F) range in seasonal mean water temperature (S. Hurlbert, unpubl. data; Watts et al., 2001). Water temperature in the Saline Habitat Complex would not be expected to preclude use of the Saline Habitat Complex by pileworms. Adult pileworms are very tolerant of low dissolved oxygen levels, surviving at least a month at 1.8 mg/L in the laboratory and have even tolerated complete anoxia for up to 27 hours under laboratory conditions (Carpelan and Linsley, 1961; Martin, 1974; Kristensen, 1983).

Kuhl and Oglesby (1979) investigated the reproduction and survival of pileworms from the Salton Sea and concluded that reproduction would be successful at salinities at least as high as 45,000 mg/L and probably as high as 50,000 mg/L. The pileworm also shows considerable adaptation to low salinity and survives well to 29,000 mg/L (Oglesby, 1965; Martin, 1974). Even though pileworm atoke can survive at lower salinities, pileworms cannot reproduce at salinities lower than 5,000 to 8,000 mg/L (Kuhl and Oglesby, 1979).

Salinity in the Saline Habitat Complex would be adaptively managed to provide a range of salinities above 20,000 mg/L and cells with fish would be maintained at salinities less than 60,000 mg/L. Because the shallow water in the Saline Habitat Complex is anticipated to be fully mixed and aerated, dissolved oxygen levels would be expected to remain within the range suitable for pileworms. It is anticipated that pileworms would be found in lower salinity cells and cells managed for fish production.

Barnacles

The barnacle found at the Salton Sea (*Balanus amphitrite*) is usually considered an intertidal and estuarine barnacle that naturally experiences desiccation and a wide range of salinity. This species has been observed at field salinities as high as 75,000 mg/L (Simmons, 1957). This species experienced total larval mortality at 86,400 mg/L and 50 percent mortality at 58,000 mg/L under laboratory conditions (Crisp and Costlow, 1963; Perez, 1994). Survival over four weeks was not significantly affected at salinities up to 74,900 mg/L (Perez, 1994). However, detrimental physiological changes were noted to occur at salinities over 50,300 mg/L (Simpson, 1994). Because salinity in the Saline Habitat Complex would be adaptively managed to provide a range of salinities above 20,000 mg/L and cells with fish would be maintained at salinities less than 60,000 mg/L, it would be expected that barnacles would be found in lower salinity cells, cells managed for fish production, and cells with somewhat higher salinities. Little is known about the effects of other water quality parameters (e.g., temperature, dissolved oxygen) on barnacles. However, water quality conditions in the Saline Habitat Complex are not expected to preclude use of the Saline Habitat Complex by barnacles.

Gammarid Shrimp

The Salton Sea species of gammarid shrimp (*Gammarus mucronatus)* has been reported in estuaries with salinities as low as 4,000 mg/L (Barnard and Gray, 1968) and hypersaline lagoons at over 50,000 mg/L (Hedgepeth, 1967). In microecosystem experiments using Salton Sea water and organisms, Hart et al. (1998) found that *Gammarus* appeared to be physiologically sensitive to higher salinities, with numbers declining as salinity increased. Hart et al. (1998) suggested that the effective upper salinity limit is less than 57,000 mg/L because the absence of *Gammarus* from the higher salinity microcosms could not be explained in terms of suppression by other organisms. Because salinity in the Saline Habitat Complex would be adaptively managed to provide a range of salinities above 20,000 mg/L and cells with fish would be maintained at salinities less than 60,000 mg/L, it would be expected that gammarid shrimp would be found in the lower salinity cells and cells managed for fish production. Little is known about the effects of other water quality parameters (e.g., temperature, dissolved oxygen) on gammarid shrimp. However, water quality conditions in the Saline Habitat Complex are not expected to preclude their use of the Saline Habitat Complex.

Corixids

Corixids (commonly called water boatman) belong to the family Corixidae, and constitute the largest group of aquatic insects in North America with over one hundred species. Water boatman are free swimming and, in habitats like the Great Salt Lake that are generally oxygen poor, corixids surface regularly for air. In more oxygen rich environments they can stay submerged for longer periods of time.

The corixid species found at the Salton Sea (*Trichocorixa reticulata)* has an extremely high tolerance for hypersaline conditions, as noted by Jang and Tullis (1980). It has been reported in water with salinity ranging from brackish to over 150,000 mg/L (Carpelan, 1957; Cox, 1969). Lonzarich and Smith (1997) found *Trichocorixa* to be abundant at salinities up to 90,000 mg/L throughout the year in the San Francisco Bay evaporation ponds. Because of the broad salinity tolerance of corixids, salinity would not be expected to preclude use of the Saline Habitat Complex by corixids. Little is known about the effects of other water quality parameters (e.g., temperature, dissolved oxygen) on corixids.

Chironomids (*Midges*)

Several hundred species of chironomids occur world-wide and different species may dominate populations in closely neighboring lakes, ponds, or streams. Some species favor water of drinking quality while others prefer sewage treatment ponds and similar habitats that are rich in nutrients. A few species thrive in brackish water, and one small group, the Clunioninae family, inhabits coastal marine environments. Chironomids currently occupy aquatic habitats in the Salton Sea area and are successful under a wide range of conditions in other areas. The Saline Habitat Complex would be expected to support populations of chironomids, although the species comprising the community would likely differ among the cell types and salinity regimes.

Brine Shrimp (*Artemia spp.*)

The brine shrimp species found at the Salton Sea (*Artemia franciscana*) has a wide temperature tolerance. Larsson (2000) reports that in ponds in the San Francisco Bay area, the optimum temperature for *A. franciscana* is 21 to 31 °C (70 to 88 °F). Bernaerts et al. (1987) reported the lower lethal temperature for male and female *Artemia* from four strains (Great Salt Lake, Macau, San Francisco salt ponds, and San Francisco Bay) as 5 °C (41 °F). The higher lethal value for male *Artemia* from the Great Salt Lake, Macau, and the salt ponds was reported as 45 °C (113 °F), while male *Artemia* from San Francisco Bay only survived up to 35 °C (95 °F). Female *Artemia* from the four strains show a temperature tolerance up to 40 °C (104 °F). Because of the broad thermal tolerance of brine shrimp, water temperature is not expected to preclude use of the Saline Habitat Complex by brine shrimp.

Brine shrimp occur in salt ponds adjacent to the San Francisco Bay that have salinities ranging from 70,000 to 200,000 mg/L, but are most common when the range is between 90,000 and 150,000 mg/L (Maiss and Harding-Smith, 1992). Hammer and Hurlburt (1992) found that *A. franciscana* grows well in Salton Sea water adjusted to salinities over the range of 38,000 to 125,000 mg/L. Predaceous invertebrates are thought to prevent *Artemia* from colonizing natural waters of lower salinity (Hart et al., 1998). Because of their preference for higher salinities and competition or predation pressure at lower salinities, brine shrimp likely would be restricted to higher salinity cells within the Saline Habitat Complex.

Brine Flies

Brine flies (family Ephydridae) are present at the Salton Sea and can be very abundant in some areas of California. For example, brine flies are found in the millions along the shores of Mono Lake in Northern California (BUGBIOS, 2006). Several species of brine fly are found in the wetlands and high salinity ponds adjacent to San Francisco Bay (Maffei, 2000). Brine fly larvae are tolerant of high salinities. Brine fly larvae occur and brine flies reproduce in the north arm of the Great Salt Lake at a salinity of 330,000 mg/L, but numbers are fewer than in the somewhat less saline south arm of the lake (Post, 1977). Because of their preference for high salinities, brine flies likely would be restricted to higher salinity cells within the Saline Habitat Complex.

Fish

Tilapia are expected to be the dominant fish species supported in the Saline Habitat Complex and would provide a forage base for piscivorous birds using the complex. Other species that could inhabit the Saline Habitat Complex include mosquitofish, sailfin molly, and longjaw mudsucker. The endangered desert pupfish currently found along the shoreline of the Salton Sea and in the drains likely could be supported in the Saline Habitat Complex depending on location, construction, and water source used. Desert pupfish use of the Saline Habitat Complex also could depend in part on whether habitat managers believed desert pupfish populations supported in the Saline Habitat Complex would provide an overall benefit for the species.

Tilapia

Because they show a broad temperature and salinity tolerance (Costa-Pierce and Riedel, 2000b) and feeding on a variety of foods (Mironova, 1969; Trewavas, 1983), tilapia are likely well suited for survival in the Saline Habitat Complex. Tilapia are known for tolerating low dissolved oxygen and high salinities and the ability to shift rapidly from a phytoplankton and detrital diet to alternate food sources (Maitipe and DeSilva, 1985; Suresh and Lin, 1992). These fish also have been cultured successfully in a variety of locations around the world, including fish farms adjacent to the Salton Sea. Based on their broad tolerance of salinity and other environmental conditions, tilapia would appear to be well suited for conditions expected in the Saline Habitat Complex. However, water temperatures in the Saline Habitat Complex during the winter could reach levels that would result in some mortality. Whitfield and Blaber (1979) found that tilapia avoided current speeds exceeding 370 meters/hour (0.2 miles/hour) in the laboratory. This observation suggests that the Saline Habitat Complex would need to be designed with low velocities in the flow-through cells.

The anticipated depths in the Saline Habitat Complex cells managed for fish production are expected to be sufficient to support tilapia. Riedel et al. (2002) found that the fish community at the Salton Sea was not evenly distributed; fish formed a dense “bathtub ring” along the nearshore and estuarine areas in the summer. Catches of tilapia were higher at the surface than at the bottom in pelagic gill nets during the summer, and higher productivities of tilapia (as expressed by catch per unit effort) were evident in areas closer to shore.

Observations at the Salton Sea (Riedel et al., 2002) indicate that tilapia feed on macrophytes, sediment, phytoplankton, zooplankton, and benthic food items. Based on the level of primary production and the invertebrate communities likely to be supported in the Saline Habitat Complex, tilapia likely would not be limited by foraging opportunities.

Mozambique tilapia are known to survive water temperatures from 15 to 40 °C (59 to 104 °F), but grow best at 25 to 37 °C (77 to 99 °F) (Al Amoudi et al., 1996). However, these tilapia are reported to reproduce only at water temperatures above 20 to 22 °C (68 to 72 °F) (Chervinski, 1982; Phillippart and Ruwet, 1982). Onset of cold stress has been reported for Mozambique tilapia at water temperatures below 15 °C (59 °F) (Allanson et al., 1962, 1971; Al Amoudi et al., 1996; Chmilevskii, 1998). Reported lethal minimum temperatures range from 5.5 to 12 °C (42 to 54 °F) (Costa-Pierce and Riedel, 2000b).

Redbelly tilapia are also noted for their hardiness and tolerance of a wide range of temperature (7 to 42 °C [45 to 108 °F]) and salinity (up to 45,000 mg/L) (Chervinski, 1982). Costa-Pierce (2001) reported capturing redbelly tilapia that had already spawned in the Salton Sea in March of 1995 when the temperature was 15 °C (59 °F) and salinity 40,000 mg/L. Like the Mozambique tilapia, redbelly tilapia are adversely affected by cold water temperatures.

Anticipated water temperatures in the Saline Habitat Complex cells would be below the temperature where tilapia begin to experience cold stress during the fall and winter months. Water temperatures in the Saline Habitat Complex cells during the winter could also reach levels below the lethal thermal minimum for tilapia. Numerous winter fish kills involving tilapia have occurred at the Salton Sea and are thought to be temperature related (Costa-Pierce and Riedel, 2000b). Water temperature could be a factor limiting the production of tilapia in the Saline Habitat Complex and periodic re-introduction of tilapia into some cells might be required following extended periods of cold weather.

Sardella et al. (2004) found that tilapia from the Salton Sea can tolerate salinities up to 65,000 mg/L and show little to no change in physiological parameters. Mozambique hybrid tilapia are currently found in the Salton Sea at salinities of 46,000 to 48,000 mg/L and redbelly tilapia are found in the drains. Costa-Pierce and Riedel (2000) postulated that tilapia in the Salton Sea could successfully acclimate to salinities as high as 60,000 mg/L. Because salinity in the Saline Habitat Complex would be adaptively managed to provide a range of salinities above 20,000 mg/L and cells with fish would be maintained at salinities less than 60,000 mg/L, it would be expected that tilapia would be found in the lower salinity cells managed for fish production.

Chervinski (1982) suggests that tilapias are able to tolerate dissolved oxygen levels as low as 1 ppm (about 1 mg/L) and may use atmospheric oxygen when levels drop below 1 mg/L. Because areas of 6 feet or less in the Saline Habitat Complex cells likely would remain mixed and aerated, low dissolved oxygen levels are not expected to preclude use of entire cells by tilapia or other fish species. There is the potential for high oxygen demand and dissolved oxygen depletion during overnight and windless periods that could result in low dissolved oxygen levels in the morning in the Saline Habitat Complex cells. Dissolved oxygen levels in the Saline Habitat Complex are expected to be similar to levels typically found in tropical fish ponds. Tropical fish ponds where dissolved oxygen levels that drop below 1 mg/L on a daily (overnight) or infrequent basis remain supportive of tilapia aquaculture as well as other fish communities (FAO, 1986; Yi et al., 2003). Although periods of low dissolved oxygen would not likely preclude the use of the Saline Habitat Complex cells by tilapia, other less tolerant species could experience mortality during these events.

Shallow ponds at the Brawley and Imperial wetland areas provide a local example of shallow eutrophic ponds with a temperature and wind regime nearly identical to that expected for the Saline Habitat Complex cells (but with much reduced wind fetch due to their smaller size). Monitoring data from ponds at the Brawley and Imperial wetland areas suggest that these local ponds experience periodic oxygen depletion and cool winter temperatures, yet continue to support tilapia.

Other Fish Species

Various members of the fish community that currently occupy the Salton Sea and adjacent rivers and drains likely would persist in the water bodies constructed as part of restoration and would continue to provide a forage base for fish-eating birds. This community, with the exception of desert pupfish, is the product of past introductions and the ability of those species to tolerate conditions at the Salton Sea. If changes in conditions following restoration impaired the ability of the Saline Habitat Complex to support the current fish community, fish species better adapted to the conditions following restoration could be introduced as part of future habitat management.

Community Structure Anticipated in the Saline Habitat Complex

Communities established in the Saline Habitat Complex likely would fall into two broad categories; those that support fish and those that would not support fish. This initial division is an important one because the presence or absence of fish would be a primary driver of community structure. Fish (primarily tilapia) likely would be excluded in cells with salinities higher than about 60,000 mg/L. These hypersaline communities likely would be dominated by salt-tolerant invertebrates that could be released from constraints imposed by the presence of predators and competitors at lower salinities. Fish also might be deliberately excluded from some lower salinity cells to allow higher levels of invertebrate productivity in support of a suite of bird species that do not feed on fish.

The anticipated food web for the Saline Habitat Complex is relatively short and would differ between low (less than 60,000 mg/L) and high (greater than 60,000 mg/L) cells (Figures H1-14 and H1-15). The bottom of the food web would be made up of bacteria, algae, and other plant material/detritus. These basic food sources are consumed higher on the food web by an assemblage of aquatic invertebrates dominated in lower salinity water by pileworms, amphipods, midges, and water boatmen, and in higher salinity water by brine flies and brine shrimp. Some species can withstand a broad range of salinities. Tilapia represent the primary vertebrate species that provide the forage base for fish-eating birds. They consume a wide variety of nutrient sources including invertebrates, algae, and detritus. The top of the food web includes groups of invertebrate-foraging birds and fish-foraging birds. Representative invertebrate foragers include birds that prefer to forage for invertebrates in open water such as ruddy duck, eared grebe, bufflehead, and common goldeneye. Shoreline invertebrate foragers include such species as black-necked stilt, American avocet, black-bellied plover, ruddy turnstone, and western sandpiper. Species that forage in open water for fish include American white pelican, brown pelican, and double-crested cormorants. Examples of birds that forage for fish in shallow shoreline areas include black skimmer, Caspian tern, Forster’s tern, and great blue heron.

Anticipated Wildlife Use of the Saline Habitat Complex

The Saline Habitat Complex is intended to encourage invertebrate and avian diversity by creating a range of conditions that support avian foraging opportunities. Each of the cells would be expected to perform differently (in terms of bird species composition and density) based primarily on salinity and water depth, but also on the invertebrate (and fish) communities they would support. The following discussion identifies the general anticipated use of each of the cell types within the Saline Habitat Complex. These cell types are conceptual in nature and represent a reasonable range of conditions anticipated in the Saline Habitat Complex. The actual design and characteristics would be developed in the project-level analyses.

Type 1 Saline Habitat Complex cells with salinity between 20,000 to 60,000 mg/L would be expected to support invertebrates and forage fish. Birds that would be expected to forage in the open water portion of Type 1 Saline Habitat Complex include American white pelican, brown pelican, double-crested cormorant. Eared grebe, ruddy duck, bufflehead, and common goldeneye would forage on invertebrates in open water areas. Depth of the pools (up to 15 feet) would provide areas where fish and invertebrates could avoid predation by birds. Birds expected to use the shorelines of the islands and Berms include

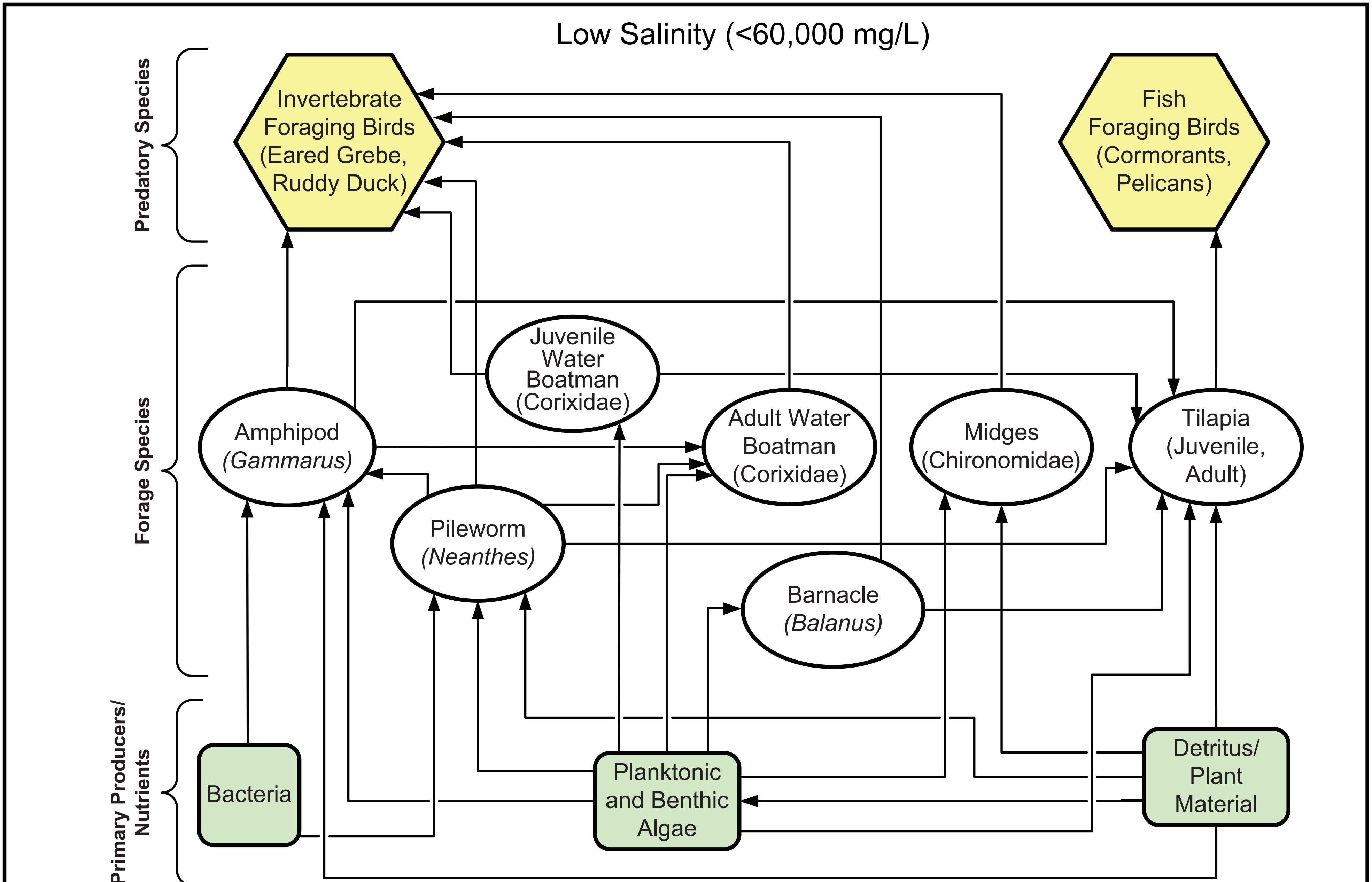

FIGURE H1-14
ANTICIPATED FOOD WEB FOR LOW-SALINITY SALINE HABITAT COMPLEX

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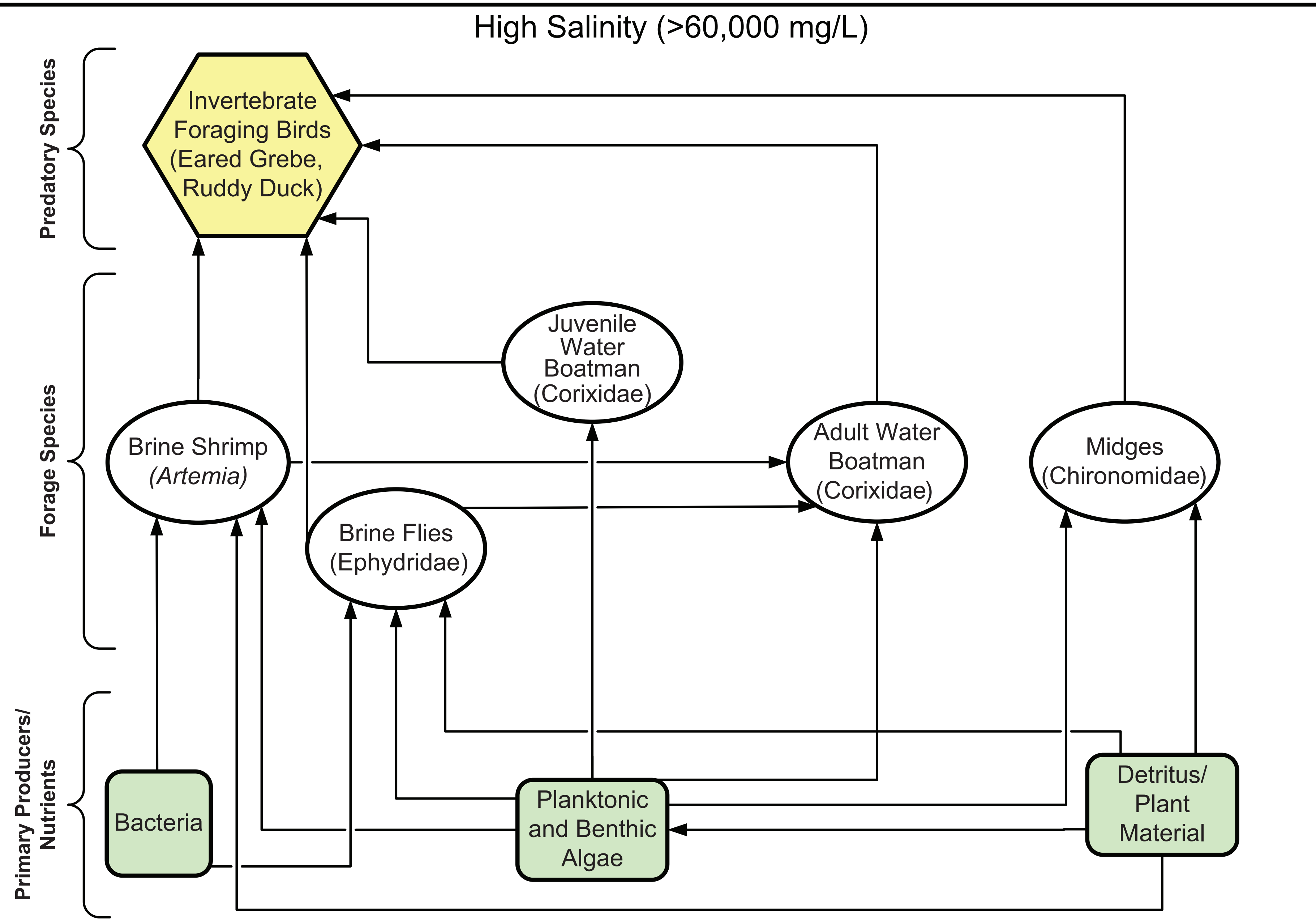

FIGURE H1-15
ANTICIPATED FOOD WEB FOR HIGH-SALINITY SALINE HABITAT COMPLEX

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black-necked stilt, American avocet, black-bellied plover, ruddy turnstone, and western sandpiper. Birds expected to use the islands for nesting or roosting include double-crested cormorant, gull-billed tern, Caspian tern, black skimmer, American white pelican, brown pelican, and California gull. Artificial snags would be expected to attract double-crested cormorant, great egret, snowy egret, cattle egret, and black-crowned night heron.

Type 2 Saline Habitat Complex cells would have salinity between 20,000 to 200,000 mg/L. The portions of the Saline Habitat Complex with salinity between 20,000 and 60,000 would be expected to support invertebrates and fish. Above 60,000 mg/L, fish likely would not be present and the species assemblage would be dominated by invertebrates. Type 2 Saline Habitat Complex would support a bird assemblage similar to the birds expected to use Type 1 Saline Habitat Complex. Depth of the pools (up to 10 feet) would provide areas where fish and invertebrates could avoid predation by birds, supporting sustainable forage production.

Type 3 Saline Habitat Complex cells would have salinity between 20,000 to 200,000 mg/L. The portions of the Saline Habitat Complex with salinity between 20,000 and 60,000 would be expected to support invertebrates and fish. Above 60,000 mg/L, fish likely would not be present and the species assemblage would be dominated by invertebrates. The shallow aspect of Type 3 Saline Habitat Complex would favor invertebrate production over fish production because of lack of refuge areas (pools) for young fish. Bird usage of Type 3 Saline Habitat Complex would be dominated by wading or diving birds that prey primarily on invertebrates such as black-necked stilt, American avocet, black-bellied plover, ruddy turnstone, and western sandpiper. At salinity greater than 60,000 mg/L, birds that prey on brine fly and brine shrimp, such as eared grebe, would dominate.

Because the Saline Habitat Complex represents an environment (particularly the highly saline cells) not currently present at the Salton Sea, the extent to which it would be used by birds at the Salton Sea is uncertain. However, estimates can be made by comparison to similar habitats located elsewhere. One environment comparable to the Saline Habitat Complex is the salt ponds adjacent to San Francisco Bay. The salt ponds are similar to the Saline Habitat Complex in that they are relatively shallow and composed of cells with a broad range of salinities. In addition, bird use of the salt ponds is relatively well understood (e.g. Takekawa et al., 2001, Warnock et al., 2002). Observations at the salt ponds suggest that a diverse avian community could be supported in Saline Habitat Complex and that bird species composition and level of use could be influenced through management of depth and salinity. Table H1-3 identifies the bird species associated with various salinity levels at the salt ponds.

Table H1-3
Bird Species Associated with Different Salinity Ranges

Species	0 to 50,000 mg/L	50,000 to 100,000 mg/L	100,000 to 150,000 mg/L	150,000 to 200,000 mg/L
American Coot	X			
Green-winged Teal	X			
Gadwall	X			
Northern Pintail	X			
American Wigeon	X			
Red-breasted Merganser	X			
American White Pelican	X			
Pied-billed Grebe	X			
Canvasback	X			
Glaucous-winged Gull	X			
Mallard	X	X		

Table H1-3
Bird Species Associated with Different Salinity Ranges

Species	0 to 50,000 mg/L	50,000 to 100,000 mg/L	100,000 to 150,000 mg/L	150,000 to 200,000 mg/L
Common Goldeneye	X	X		
Ruddy Duck	X	X		
Clark's Grebe	X	X		
Western Grebe	X	X		
Double-crested Cormorant	X	X		
Forster's Tern	X	X		
Marbled Godwit	X	X		
Black-bellied Plover	X	X		
Red Knot	X	X		
Long-billed Curlew	X	X		
Dowitcher	X	X		
Semipalmated Plover	X	X		
Western Gull	X	X		
Ring-billed Gull	X	X	X	
Mew Gull		X		
Bufflehead		X		
Lesser Scaup		X	X	
Greater Scaup		X	X	
Killdeer		X	X	
Eared Grebe		X	X	
Bonaparte's Gull		X	X	
Greater Yellowlegs		X	X	
American Avocet		X	X	
Sanderling		X	X	
Black-necked Stilt		X	X	X
Western Sandpiper		X	X	X
Snowy Plover		X	X	X
Dunlin		X	X	X
Least Sandpiper		X	X	X
Willet		X	X	X
Ruddy Turnstone		X	X	X
California Gull		X	X	X

Marine Sea

Several alternatives include a Marine Sea to stabilize and retain a portion of the habitat values currently provided by the Salton Sea. The size of the Marine Sea varies by alternative, but generally represents a substantially smaller water body than the current Salton Sea. The range of depths would depend on the ultimate configuration and location of the Marine Sea, but likely would extend to 25 feet deep or more. The stable Marine Sea would be designed to maintain a target salinity range of 30,000 to 40,000 mg/L.

Under these conditions, the Marine Sea would be expected to support fish and invertebrate communities similar to recent historical conditions in the Salton Sea, and provide shoreline and open water habitats that would continue to support birds. While the primary purpose of the Marine Sea would be to retain habitat value, its reduced size and greater attractiveness for recreation could result in an increased level of human disturbance that could diminish the value of the habitat for wildlife.

The present understanding of the Salton Sea ecosystem is based on information related to the physical and chemical processes at the Salton Sea; biology of invertebrates, fishes, and birds; food web; diseases; and the ecological function of the various habitats. Figure H1-16 depicts some of the major stressors/pressures on habitats and species in the system. High nutrient levels and high salinity levels are the sources of the majority of pressures on the physical environment and the invertebrate, fish, and bird species associated with the Salton Sea ecosystem.

Currently, most of the open water areas of the Salton Sea are subject to periodic events that can make large portions of the Sea lethal or uninhabitable to most aquatic life. During parts of the year, the Salton Sea becomes stratified with cooler water forming a distinct layer below the warmer surface water. This lower layer becomes anoxic (deprived of oxygen) because of its isolation from the surface and decomposition of organic material (algae) that settles from the upper water layer. The combination of anoxia and decomposition of organic materials in the lower water layer and sediments produces toxic compounds, such as hydrogen sulfide, that are periodically released to the surface waters when the stratification breaks down during high winds and seasonal changes in temperature (Figure H1-17). During these turnover events, aquatic life (including fish) can be destroyed over vast areas of the Sea. The effect of these events is less pronounced in the near shore areas that remain oxygenated year round. Recent modeling (Appendix D) suggests that the duration of stratification and the magnitude of these events that produce hydrogen sulfide could be influenced by the size of the Marine Sea.

The Marine Sea would retain a portion of the function and value of shoreline and deep open water habitat. The characteristics of the deltas, however, would change because of modification of the river mouths to accommodate water distribution and conveyance for habitat maintenance and air quality management. Flows entering the Marine Sea would not carry the silt and nutrient loads that currently contribute to the value of delta habitats.

Anticipated Water Quality

The ability of the Marine Sea to support invertebrates, fish, and birds would be strongly influenced by water quality, particularly dissolved oxygen and toxic constituents like hydrogen sulfide. Currently, the Salton Sea is highly eutrophic – a condition responsible for both the Salton Sea's high productivity and the periodic conditions that are destructive to fish and wildlife. The Marine Sea would retain most of the characteristics of the current Salton Sea, including many of the same factors that influence stratification and the quality of the habitat. The size of the Marine Sea varies by alternative, but generally represents a substantially smaller water body than the current Salton Sea. The range of depths would depend on the ultimate configuration and location of the Marine Sea. Changes in the surface area and/or depth of the Marine Sea relative to the current Salton Sea would result in changes in the degree of stratification and the frequency of turnover events.

Salinity

The Marine Sea would be maintained within a target salinity range of 30,000 to 40,000 mg/L. This salinity range would be maintained to provide conditions suitable for support of a diverse assemblage of invertebrates and marine fish, reduce or prevent encroachment by rooted vegetation, and reduce vectors (e.g., mosquitoes).Within this salinity range, the Marine Sea would be expected to support fish and invertebrate communities similar to current or recent historical conditions in the Salton Sea.

Water Temperature

Modeling of the temperature and wind regime for a Marine Sea (Appendix D) predicts that annual average water temperatures would decline in a smaller Marine Sea as compared to the Salton Sea. Annual minimum temperatures may be slightly lower and annual maximum temperatures would be comparable to those in the current Salton Sea.

Modeling of the temperature and wind regime for a Marine Sea predicts more pronounced stratification than occurs in the current Salton Sea, due to decreased surface area which decreases the wind fetch. The stratification is expected to be both stronger (larger difference between surface and bottom temperatures) and longer in duration for a Marine Sea of similar depth to the Salton Sea. Increased stratification could cause accumulation of constituents released from decomposition of organic materials in the lower water layer and sediments, including ammonia and hydrogen sulfide, due to depression of dissolved oxygen concentrations in the hypolimnion (deeper water). However, a shallower Marine Sea could result in more frequent mixing, and, hence, less stratification and accumulation of ammonia and hydrogen sulfide than a deeper Marine Sea.

Selenium

Most of the selenium currently found in the Salton Sea is located within deep, anoxic sediments where the selenium is relatively unavailable to biota because of low exposure rates (USGS, 2003). Modifications to the Salton Sea that would decrease water depth and increase oxidation of the deep sediments would tend to increase overall selenium bioavailability. However, thermal stratification and development of anoxic sediments would tend to decrease overall selenium bioavailability. Since stratification in the Marine Sea is expected to be both stronger and longer in duration than the current Salton Sea, the bioavailability of selenium in the Marine Sea would be expected to decrease relative to conditions in the current Salton Sea (Appendix F).

Dissolved Oxygen

The expected dissolved oxygen regime for the Marine Sea is anticipated to be lower in the hypolimnion (deep waters), on average, and higher in the epilimnion (surface waters), on average, than in the current Salton Sea. The increased dissolved oxygen in the surface waters would result from increased photosynthetic activity due to increased algal production (below), and the decreased dissolved oxygen in the hypolimnion would be associated with decreased mixing but continued decomposition of organic materials. However, a shallower Marine Sea would mix more frequently, and, hence, dissolved oxygen levels would not be depressed as much as in a deeper Marine Sea. The predicted dissolved oxygen regime for the Marine Sea is slightly better from a habitat perspective than in the current Salton Sea. The number of days with surface dissolved oxygen concentrations below 2 mg/L is predicted to decrease.

Nutrients and Other Constituents

It is anticipated that there would be a significant increase in algal production, and, hence, chlorophyll concentration, in the surface waters of the Marine Sea compared to current conditions in the Salton Sea (Appendix D). Ortho-phosphate concentrations in the smaller Marine Sea are expected to be similar to current conditions in the Salton Sea. Like the current Salton Sea, the Marine Sea is expected to be phosphorus limited during the spring and summer months.

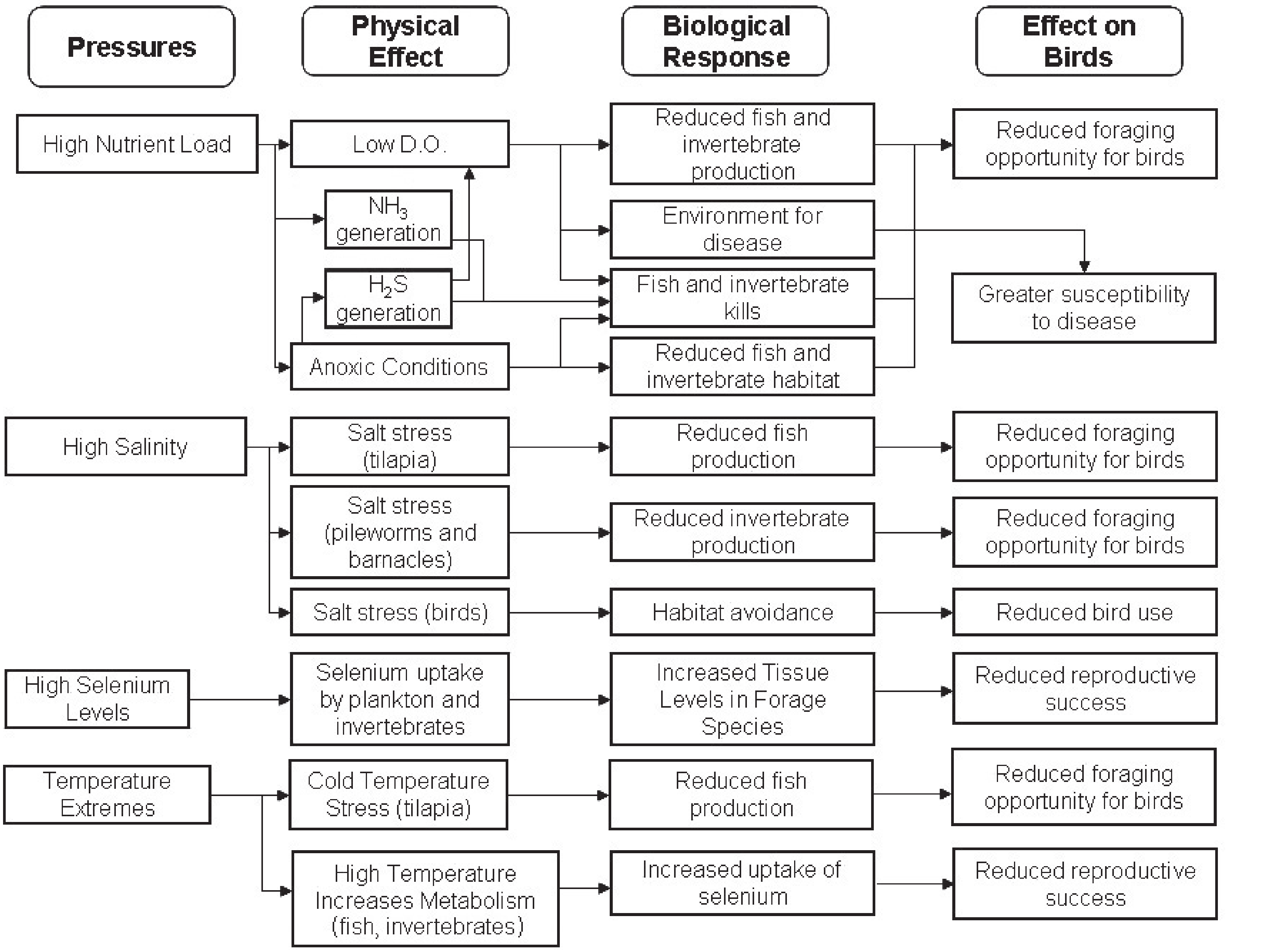
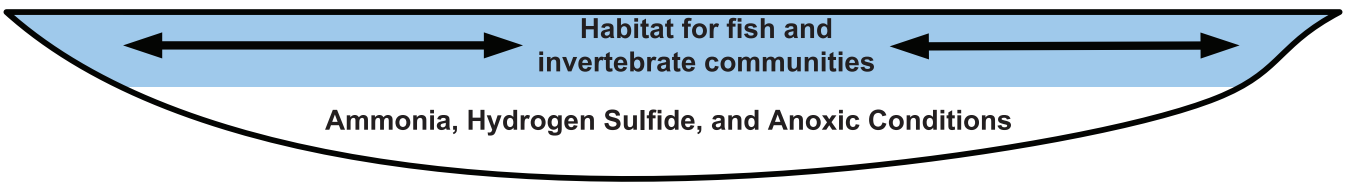


FIGURE H1-16
RELATIONSHIP OF ECOLOGICAL PRESSURES AND EFFECTS ON BIRDS AT THE SALTON SEA

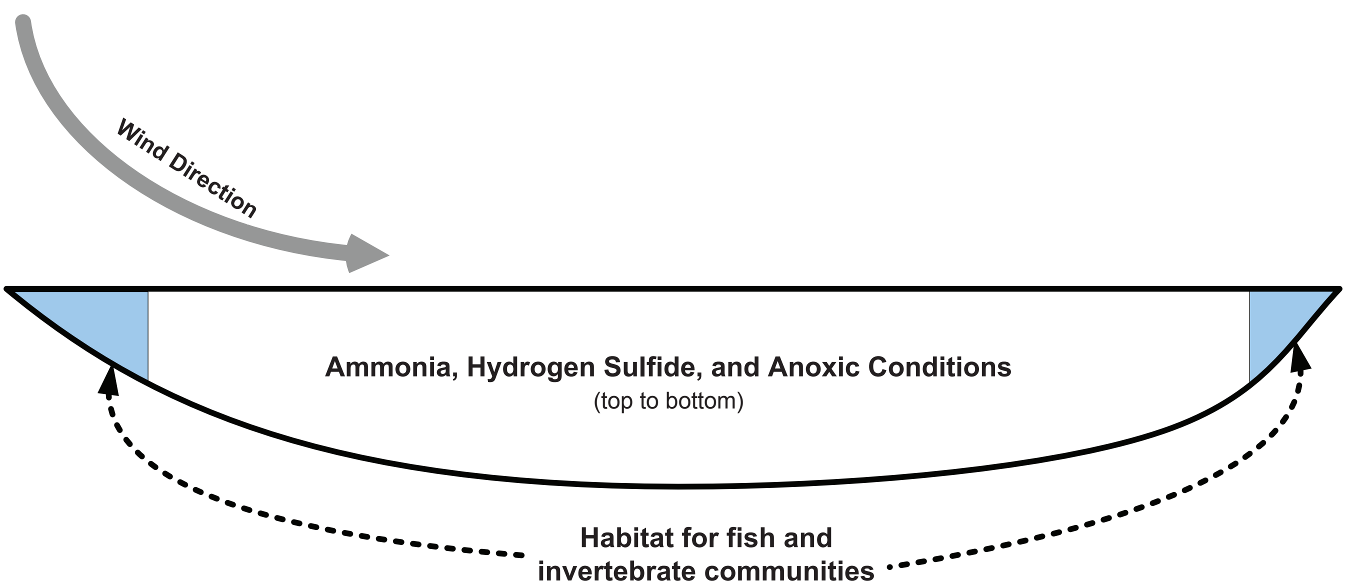
Salton Sea under “No Wind” Condition



Under “No Wind” conditions, the Salton Sea is calm. Thermal stratification and decomposition of organic matter results in the formation of anoxic (low oxygen) conditions in the deeper water and sediment. Anoxic conditions result in increasing levels of ammonia and hydrogen sulfide.

Habitat for fish and invertebrate communities is limited to the upper portion of the water column and the nearshore areas.

Salton Sea under “Windy” Condition



Under “Windy” conditions, the Salton Sea mixes due to water movement. Ammonia, hydrogen sulfide, and anoxic water mix with the surface water rending the majority of the Salton Sea unsuitable for aquatic life. Habitat for fish and invertebrate communities is limited to the nearshore areas.

FIGURE H1-17
DIAGRAM DEPICTING A WIND EVENT RESULTING IN ANOXIC CONDITIONS AT THE SALTON SEA

Thermal stratification would also affect ammonia concentrations in the Marine Sea. Ammonia concentrations in the hypolimnion would start to increase under stratified conditions once the dissolved oxygen is depleted. Because this is expected to occur earlier in the smaller Marine Sea of the same depth as the current Salton Sea, ammonia concentrations would likely begin to build sooner and peak at higher levels than in the current Salton Sea. The stronger stratification could delay the timing of a full mixing event, which coupled with the higher level to which ammonia has concentrated in the hypolimnetic waters, would contribute to the inability of the Marine Sea to recover from the depressed dissolved oxygen condition. Modeling suggests that there would not be enough oxygen in the Marine Sea to completely convert the ammonia to nitrate after the mixing event. However, a shallower Marine Sea would mix more frequently, and thus ammonia would not build to such high levels.

The increased thermal stratification in the Marine Sea discussed above also allows for a build-up of hydrogen sulfide in the hypolimnion compared to current conditions in the Salton Sea. When the stratification finally breaks down, hydrogen sulfide concentrations in the surface waters are expected to increase rapidly, peaking at a level higher than predicted for the Salton Sea under current conditions. Even though some aspects (e.g., salinity) of water quality would be improved relative to the conditions in the current Salton Sea, the modeling results suggest that conditions in the Marine Sea of a depth similar to the Salton Sea would likely continue to produce periodic fish kills. Because of the sharper stratification and greater duration of stratified conditions in the Marine Sea, mixing events that release hydrogen sulfide into the water column could be more severe than those that occur in the current Salton Sea and result in greater impact to aquatic organisms. The severity of these events, however, would diminish in the future as nutrient levels (both internal and external loads) were reduced. A shallower Marine Sea would mix more frequently, would have less buildup of ammonia and hydrogen sulfide, and could hence provide improved conditions compared to the current Salton Sea.

Biological Characteristics

Many of the species currently found in the Salton Sea and the rivers and drains flowing to the Salton Sea would be expected to inhabit the Marine Sea. Life history attributes and water quality tolerance of species currently found in the Salton Sea and likely to be found in the Marine Sea were described above for the Saline Habitat Complex. Similar to the current Salton Sea, water quality conditions could result in periodic fish and invertebrate mortality events. However, it is unlikely that water quality conditions in the Marine Sea would result in complete mortality of these aquatic resources. Therefore, many species currently found in the Salton Sea would be expected to persist in the Marine Sea.

Restoration components could improve water quality to the extent that the Marine Sea supports higher densities of fish and invertebrates than current conditions. However, the smaller Marine Sea likely would not support the same absolute levels of aquatic species abundance recently seen at the Salton Sea. Thus all alternatives containing a Marine Sea would need additional habitat creation to address the objectives of restoration. Restoration of the historically important sport fish or other fish that could provide a sport fishery would require introductions of these species from other areas.

Community Structure Anticipated in the Marine Sea

The anticipated food web in the Marine Sea would be similar to that of the current Salton Sea and that anticipated in the low salinity cells of the Saline Habitat Complex with salinity less than 60,000 mg/L described above. The bottom of the food web would be made up of bacteria, algae, and other plant material/detritus. These basic food sources would be consumed higher on the food web by an assemblage of aquatic invertebrates, likely dominated by pileworms, barnacles, amphipods, midges, and water boatman. Fish species could include representatives of the three functional groups historically found in the Salton Sea (forage fish, sport fish, and desert pupfish). Tilapia likely would dominate a suite of forage fish species that could include species currently found in the Salton Sea such as western mosquitofish, sailfin molly, and longjaw mudsucker. These species could provide the forage base for fish-eating birds and introduced fish. Salinity levels anticipated in the Marine Sea would likely allow introduction and establishment of a variety of marine sport fish species, including those that were historically present and provided a recreational fishery. Shoreline areas at the interface of drains emptying directly into the Marine Sea would continue to provide habitat and connectivity for the endangered desert pupfish.

Anticipated Wildlife Use of the Marine Sea

Because the characteristics of the Marine Sea would largely mimic current conditions at the Salton Sea (except for reduced salinity), the Marine Sea would be expected to support fish and invertebrate communities similar to current or recent historical conditions in the Salton Sea, and provide shoreline and open water habitats that would continue to support birds. Birds that would be expected to forage on fish in the deeper, open water portion of the Marine Sea include American white pelican, brown pelican, and double-crested cormorant. Eared grebes, ruddy ducks, bufflehead, and common goldeneye would forage on invertebrates in open water areas. Birds expected to use the shoreline areas include black-necked stilt, American avocet, black-bellied plover, ruddy turnstone, and western sandpiper. The reduced area of the Marine Sea relative to the current Salton Sea would likely support reduced numbers of birds and fish compared to the current and historical Salton Sea.

Concentric Waterways (Rings and Lakes)

Concentric waterways (referred to in the PEIR as Concentric Rings and Lakes) would be water bodies constructed parallel to the shoreline of the Salton Sea. These water bodies would be constructed along the contours of the Sea Bed, and could be over 1 mile in width in locations where the bathymetry is relatively flat. Inflows would enter the first concentric waterway and progressively discharge via gravity into the second and subsequent waterways. Water would eventually discharge to a Brine Sink that would form at the lowest elevations on the Sea Bed. The first concentric waterway would be constructed along the contour parallel to the shoreline. The second and any additional waterways would be constructed in a similar manner along lower contours. The waterways would be formed by construction of Berms using material excavated from the Sea Bed or Perimeter Dikes using imported rock.. The waterways would be designed and managed for a salinity of 20,000 to 60,000 mg/L.

The design of these water bodies results in an inherent increase in edge and shallow water area. The first concentric waterway would capture some or all of the current shoreline; subsequent waterways would create additional shoreline. In some configurations, there could be over 1 mile of exposed Sea Bed between the waterways. Similar to the Saline Habitat Complex, these waterways could be constructed in a manner that creates deeper excavated areas and islands to increase habitat complexity and the opportunity for greater species diversity. Areas within the water body excavated to generate the material needed to create the Berms could be as deep as 15 feet. The Berms and Perimeter Dikes would be armored with rock to prevent water erosion, which would provide substrate, cover, and refuge for invertebrates and fish. These waterways would be expected to support invertebrate communities and fish (in those with suitable salinity levels). As part of the project-level analyses, structures that would support nesting and roosting by colonial waterbirds could be considered.

Similar to the Saline Habitat Complex cells, the concentric waterways are likely to support production of algae, invertebrates, and fish with little potential for water quality degradation (dissolved oxygen depletion, hydrogen sulfide production). The frequent and significant winds combined with the open fetch and shallow depth of the waterways would support a freely mixed environment that would mitigate any potential problems associated with the naturally eutrophic or hypereutrophic conditions. The shallowest waterways of less than 6 feet would experience the greatest temperature extremes but should maintain adequate dissolved oxygen to support fish. The aquatic and avian communities in the concentric waterways are anticipated to be similar to the communities anticipated in the Saline Habitat Complex with similar salinity.

Brine Sink

Under all of the alternatives, flows from the managed habitats and Air Quality Management areas would flow to the Brine Sink that would be located at the lowest elevation on the Sea Bed. Because inflows into the basin vary, the Brine Sink would be the water body that allows stable water flow to the habitat elements. Salinity, surface elevation, volume, and depth would fluctuate in the Brine Sink over time. The habitat value of the Brine Sink also would vary, with an expectation that the values would diminish in the future as its surface area decreases and salinity increases. The rate at which this transformation would occur depends in large part on inflows. Under some alternatives, the Brine Sink would be restricted to two relatively small, highly saline water bodies at the lowest elevations in the Sea Bed.

Initially, the Brine Sink would be expected to function in a manner similar to the current Salton Sea and support comparable levels of use by fish and wildlife. As salinity increased, the Brine Sink would become less suitable for support of organisms not adapted to high salinities and would become dominated by salt-tolerant invertebrates, such as brine flies and brine shrimp. The community would resemble the high-salinity cells of the Saline Habitat Complex. Eventually, salinity in the Brine Sink would exceed 200,000 mg/L, the upper salinity tolerance of brine flies and brine shrimp. When these important food items are no longer able to survive in the Brine Sink, avian use would likely cease.

Air Quality Management Areas

As described in Appendix H-3, various approaches have been evaluated for controlling dust in areas permanently or intermittently exposed under the alternatives. In general, approaches that would require minimal water (low water use or dry control measures) such as stabilization with brine (e.g., enhanced salt crust), gravel cover and chemical stabilization would create areas that are not conducive to wildlife use. Approaches that would require water (water based control measures) such as use of water efficient vegetation could provide areas used by wildlife.

Water efficient plants would be selected for tolerance of water with high salinity, low water demands, low maintenance needs, and similarity in nature to native desert plant communities. Plants that would meet this requirement include Parry's saltbush and Mojave seablite. Additional detailed studies would be required during project-level analyses to identify the most suitable plant species for use in the playa environment. Plants would be placed in rows about 5 to 10 feet apart with individual plants about 3 feet apart along the rows. Each plant would grow to about 3-feet in diameter and the total canopy would cover about 30 percent of the planted area. In addition to the planted or naturally occurring salt-tolerant plants, it is expected that these areas would support terrestrial invertebrates and limited numbers of reptiles (snakes and lizards), small mammals, and birds.

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APPENDIX H-1, ATTACHMENT 1

Birds and Associated Habitats within the Salton Sea Area

Birds and Associated Habitats within the Salton Sea Area

Family/Species	Salton Sea							Other Areas within the Salton Sea Watershed						
	Deep Open Saltwater		Shoreline/Shallow Saltwater					Managed Wetlands		Upland Habitat		Other Habitats		
(245 SPECIES)	Fish as Forage	Invertebrates as Forage	Fish as Forage	Invertebrates as Forage	Colonial Tree Nester/Roosters	Colonial Ground Nester/Roosters	River Mouths/Delta	Freshwater Marsh associates	Saltwater Wetland Associates	Agriculture Associates	Tree/shrub Associates	Developed area Associates	Xeric Tree/Shrub Associates	Other
Family: Gaviidae														
Common loon	X						X							
Family: Podicipedidae														
Pied-billed grebe							X	X	X					
Eared grebe		X		X			X		X					
Western grebe	X		X				X		X					
Clark's grebe	X		X				X		X					
Family: Pelecanidae														
American white pelican	X		X			X	X		X					
Brown pelican	X					X	X		X					
Family: Phalacrocoracidae														
Double-crested cormorant	X		X		X	X	X		X					
Family: Ardeidae														
American bittern								X						
Least bittern								X						
Great blue heron			X	X	X		X	X	X	X				
Great egret			X	X	X		X	X	X	X				
Snowy egret					X			X	X					

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Cattle egret					X					X				
Green heron								X			X			
Black-crowned night-heron			X	X	X		X	X	X					
Family: Threskiornithidae														
White-faced ibis					X		X	X		X				
Family: Ciconiidae														
Wood stork				X	X		X			X				
Family: Anatidae														
Fulvous whistling-duck								X						
Greater white-fronted goose								X		X				
Snow goose								X		X				
Ross's goose								X		X				
Cackling goose								X		X				
Brant							X		X					
Canada goose								X		X				
Green-winged teal							X	X	X					
Mallard							X	X	X					
Northern pintail				X			X	X	X	X				

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Blue-winged teal								X	X					
Cinnamon teal								X	X					
Northern shoveler				X			X	X	X					
Gadwall				X			X	X	X					
American wigeon				X			X	X	X	X				
Canvasback		X		X			X		X					
Redhead		X		X			X	X	X					
Ring-necked duck								X						X
Greater scaup		X		X			X		X					
Lesser scaup		X		X			X		X					
Surf scoter		X					X		X					
Common goldeneye		X		X			X		X					
Bufflehead		X		X			X		X					
Hooded merganser							X							X
Red-breasted merganser	X		X				X		X					
Ruddy duck		X					X		X					
Family: Cathartidae														
Turkey vulture														X

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Family: Accipitridae														
Osprey	X		X				X				X			
White-tailed kite Riparian										X				
Northern harrier								X		X				
Sharp-shinned hawk											X			
Cooper's hawk											X			
Harris's hawk										X	X			
Red-shouldered hawk Riparian										X	X			
Red-tailed hawk										X				
Ferruginous hawk										X				
Rough-legged hawk										X				
Family: Falconidae														
American kestrel										X				
Merlin							X	X	X	X				
Peregrine falcon							X	X	X	X				
Prairie falcon										X				

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Family: Phasianidae														
Ring-necked pheasant										X				
Gambel's quail													X	
Family: Rallidae														
Black rail								X						
Yuma clapper rail								X						
Virginia rail								X						
Sora								X						
Common moorhen								X						
American coot							X	X	X					
Family: Gruidae														
Sandhill crane						X				X				
Family: Charadriidae														
Black-bellied plover				X			X		X	X				
Western Snowy plover				X			X		X					
Semipalmated plover				X			X		X					
Killdeer				X			X		X	X				
Mountain plover										X				

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Family: Recurvirostridae														
Black-necked stilt				X		X	X		X	X				
American avocet				X		X	X		X					
Family: Scolopacidae														
Greater yellowlegs				X			X		X	X				
Lesser yellowlegs									X	X				
Solitary sandpiper								X						
Willet				X		X	X		X					
Spotted sandpiper				X						X				
Whimbrel						X			X	X				
Long-billed curlew				X					X	X				
Marbled godwit				X		X	X		X					
Ruddy turnstone				X			X		X					
Red knot				X			X		X					
Sanderling				X			X		X					
Western sandpiper				X		X	X		X					
Least sandpiper				X			X		X					
Baird's sandpiper				X			X		X					

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Pectoral sandpiper								X		X				
Dunlin				X			X		X	X				
Stilt sandpiper				X			X		X	X				
Short-billed dowitcher				X			X		X					
Long-billed dowitcher				X			X	X	X	X				
Wilson's snipe (name change)								X						
Wilson's phalarope				X			X		X	X				
Red-necked phalarope				X		X	X		X					
Family: Laridae														
Parasitic jaeger	X		X				X		X					
Laughing gull			X	X		X	X		X					
Franklin's gull			X	X		X	X		X					
Bonaparte's gull			X	X			X		X					
Heermann's gull			X	X		X	X		X					
Mew gull			X	X		X	X		X					
Ring-billed gull			X	X		X	X		X	X				
California gull			X	X		X	X		X					
Herring gull			X	X		X	X		X					

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Thayer's gull			X	X		X	X		X					
Yellow-footed gull			X	X		X	X		X					
Sabine's gull	X		X	X		X	X		X					
Gull-billed tern			X	X		X	X		X	X				
Caspian tern			X			X	X		X					
Common tern			X			X	X		X					
Forster's tern			X			X	X		X					
Least tern			X			X	X		X					
Black tern			X	X		X	X		X	X				
Black skimmer			X			X	X		X					
Family: Columbidae														
Rock dove												X		
Spotted dove										X		X		
White-winged dove										X		X		
Mourning dove										X		X		
Eurasian collard dove												X		
Inca dove												X		
Common ground-dove										X	X	X		

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Ruddy ground dove												X		
Family: Cuculidae														
Greater roadrunner													X	
Family: Tytonidae														
Barn-owl										X		X		
Family: Strigidae														
Western screech-owl											X	X		
Great horned owl											X	X		
Burrowing owl										X				
Family: Caprimulgidae														
Lesser nighthawk										X			X	
Family: Apodidae														
Vaux's swift														X
White-throated swift														X
Family: Trochilidae														
Black-chinned hummingbird												X		
Anna's hummingbird												X		
Costa's hummingbird												X		

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Calliope hummingbird												X		
Rufous hummingbird												X		
Family: Alcedinidae														
Belted kingfisher								X						
Family: Picidae														
Lewis' woodpecker												X		
Gila woodpecker												X		
Red-naped sapsucker												X		
Ladder backed woodpecker													X	
Northern flicker											X	X		
Family: Tyrannidae														
Olive-sided flycatcher											X	X		
Western wood-pewee											X			
Willow flycatcher											X		X	
Hammond's flycatcher											X	X		
Gray flycatcher													X	
Western (Pacific-slope) flycatcher													X	
Black phoebe								X			X			

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Eastern phoebe											X			
Say's phoebe										X			X	
Vermillion flycatcher											X			
Ash-throated flycatcher											X			
Western kingbird										X			X	
Family: Alaudidae														
Horned lark										X				
Family: Hirundinidae														
Tree swallow														X
Violet-green swallow														X
Northern rough-winged swallow														X
Bank swallow														X
Cliff swallow														X
Barn swallow												X		X
Family: Corvidae														
American crow												X		
Common raven (very few ravens)												X		

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Family: Remizidae														
Verdin												X	X	
Family: Sittidae														
Red-breasted nuthatch												X		
Family: Troglodytidae														
Cactus wren													X	
Rock wren													X	
Bewick’s wren											X	X	X	
House wren												X		
Marsh wren								X						
Family: Muscicapidae														
Ruby-crowned kinglet											X	X	X	
Blue-gray gnatcatcher											X			
Black-tailed gnatcatcher											X		X	
Western bluebird												X	X	
Mountain bluebird										X				
Townsend’s solitaire											X	X		
Swainson’s thrush											X	X		

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Hermit thrush											X	X		
American robin												X		
Family: Mimidae														
Northern mockingbird												X		
Sage thrasher													X	
Crissal thrasher													X	
Family: Motacillidae														
American pipit										X				
Sprague’s pipit										X				
Family: Bombycillidae														
Cedar waxwing												X		
Family: Ptilogonatidae														
Phainopepla													X	
Family: Laniidae														
Loggerhead shrike										X			X	
Family: Sturnidae														
European starling										X		X		

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Family: Vireonidae														
Warbling vireo											X	X		
Plumbeous vireo												X		
Cassin's vireo												X	X	
Family: Emberizidae														
Orange-crowned warbler											X			
Nashville warbler											X			
Lucy's warbler													X	
Northern parula												X		
Yellow warbler											X	X		
Palm warbler											X			
Black-throated gray warbler													X	
Yellow-rumped warbler											X	X	X	
Townsend's warbler												X	X	
Hermit warbler												X		
Black-and-white warbler											X	X		
MacGillivray's warbler											X		X	
Common yellowthroat								X			X			

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Wilson's warbler											X		X	
Yellow-breasted chat											X			
Summer tanager											X	X		
Western tanager												X		
Black-headed grosbeak												X		
Blue grosbeak											X	X		
Lazuli bunting											X	X		
Spotted towhee											X	X		
Abert's towhee											X	X		
Chipping sparrow												X		
Brewer's sparrow										X			X	
Vesper sparrow										X			X	
Lark sparrow										X				
Sage sparrow													X	
Great Basin savannah sparrow										X				
Large-billed savannah sparrow												X		
Fox sparrow											X	X		
Song sparrow								X			X			

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Lincoln's sparrow														
Swamp sparrow								X			X			
Golden-crowned sparrow												X	X	
White-crowned sparrow										X	X	X		
Dark-eyed junco												X		
McCown's longspur										X				
Lapland longspur										X				
Chestnut-collard longspur										X				
Smith's longspur										X				
Red-winged blackbird								X		X				
Western meadowlark										X				
Yellow-headed blackbird								X		X				
Brewer's blackbird										X		X		
Great-tailed grackle										X		X		
Bronzed cowbird												X		
Brown-headed cowbird										X				
Bullock's oriole												X		
Hooded oriole												X		

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Family/Species	Salton Sea							Other Areas within the Salton Sea Watershed						
	Deep Open Saltwater		Shoreline/Shallow Saltwater					Managed Wetlands		Upland Habitat		Other Habitats		
(245 SPECIES)	Fish as Forage	Invertebrates as Forage	Fish as Forage	Invertebrates as Forage	Colonial Tree Nester/Roosters	Colonial Ground Nester/Roosters	River Mouths/Delta	Freshwater Marsh associates	Saltwater Wetland Associates	Agriculture Associates	Tree/shrub Associates	Developed area Associates	Xeric Tree/Shrub Associates	Other
Family: Fringillidae														
House finch												X		
Pine siskin												X		
Lesser goldfinch												X	X	
American goldfinch											X	X		
Family: Passeridae														
House sparrow												X		